Effects of Weather on Physical Activity among School Children in Alberta, Canada

by

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Abstract

Background: Physical activity in children is an important part of a healthy lifestyle and contributes to the prevention of childhood overweight and obesity. However, Canadian children are not physically active enough. Weather conditions may limit physical activity levels, but little is known about how Canadian weather conditions affect physical activity in children. Understanding the effect of weather attributes on physical activity is important to guide policies and programs, and design effective interventions for the promotion of physical activity in children and prevention of overweight and obesity.

Purpose: This research investigated the effect of weather attributes on physical activity in school-aged children in Alberta, Canada.

Methods: Between March to June 2013, grade 5 students (aged 10 to 11) from 60 schools in Alberta, Canada were invited to participate in this study. Physical activity was measured objectively using time-stamped pedometers (step counts per hour), over 9 consecutive days. Weather data, including daily actual temperature, feels-like temperature, maximum and minimum temperatures, cloud coverage, and daily precipitation were obtained from local weather stations in Alberta. Multi-level mixed-effect regression models were used to estimate the effect of each of the weather attributes on the step counts, adjusted for other covariates of interest in the study. All analyses were performed for the time frame between 7:00am to 9:00pm (waking hours).

Results: 972 students and 5958 days of observation were included in the analyses. Physical activity data was considered to be valid if the pedometer was worn for a minimum of 8 hours/day

and on at least two school days and one non-school day. Cloud coverage and precipitation resulted in a substantial decline in daily step counts; in un-stratified analysis, a unit increase in cloud coverage was associated with 61 fewer step counts/day (95% CI: -99, -22), and relative to no precipitation, light (0.01-5mm) and heavy (>5mm) precipitation resulted in 209 (95% CI: -535, 116) and 1022 (95% CI: -1557, -487) fewer step counts/day, respectively. Increase in mean ambient, daily maximum and daily minimum temperature were more likely to have a positive effect on physical activity, although the associations were not statistically significant. The associations between weather attributes and physical activity differed by gender, day of the week (school day vs. non-school day), time periods on a school day (before, during, and after school hours), and activity level of the students (more active vs. less active).

Conclusions: These findings provide evidence that certain weather attributes can affect physical activity in children substantially, and should therefore be considered when evaluating physical activity levels or designing interventions to promote activity in children. In order to establish habitual physical activity at early ages, there is a need to design interventions and strategies for promotion of physical activity for suboptimal weather conditions. Results further justify a need for school policies and programs to focus on developing alternative activity opportunities to prevent a transient decline in physical activity levels when the weather is not favorable for outdoor activities.

Preface

This thesis is an original work by Sholeh Rahman. No part of this thesis has been previously published. The research projects, of which this thesis is a part, received research ethics approval from the Human Research Ethics Board (REB) of the University of Alberta under the study names the Alberta Project Promoting active Living and healthy Eating (APPLE) Schools, The Raising healthy Eating and Active Living (REAL) Kids Alberta survey, and the Healthy Schools-Healthy Future (HSHF) program.

"One thing I have learned in a long life: that all our science, measured against reality, is primitive and childlike, and yet it is the most precious thing we have."

Albert Einstein

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List of Abbreviations

APPLE Schools	Alberta Project Promoting active Living and healthy Eating Schools
REAL Kids Alberta	The Raising healthy Eating and Active Living Kids in Alberta
HSHF	Healthy Schools-Healthy Future
BMI	Body Mass Index
MVPA	Moderate to Vigorous Physical activity
MET	Metabolic Equivalent Task
CANPLAY	Canadian Physical Activity Levels among Youth
CHMS	Canadian Health Measures Survey
WHO	World Health Organization
SD	Standard Deviation

Chapter I

Introduction

1.1 Overview

Physical activity is an established determinant of health and wellness across different age groups, genders and socioeconomic subgroups [1-5]. In children and youth, physical activity is associated with several health benefits; regular physical activity during childhood can contribute greatly to the prevention of childhood overweight and obesity [6, 7], increased bone density and musculoskeletal fitness [8-11], enhanced immunity [12], protection against type II diabetes and other chronic illnesses [13, 14], and promotion of a healthier adult life [2, 7]. In addition to its health benefits, physical activity has positive effect on improved cognitive development and academic performance in children [15, 16]. Despite its benefits, many Canadian children are not sufficiently active. The new Canadian physical activity guidelines recommend that children aged 5-17 years should accumulate at least 60 minutes of moderate to vigorous physical activity (MVPA) per day in order to achieve associated health benefits [17]. However, nationally representative data show that there are low levels of physical activity among Canadian children and youth with only 9 percent of boys and 4 percent of girls meeting the recommended guidelines [18].

Substantial evidence indicates that lack of sufficient physical activity has contributed to the increasing prevalence of overweight and obesity in children [19-21]. Based on 2009-2011 Canadian Health Measures Survey (CHMS), more than 33 percent of 5-17-year-old children are overweight or obese [22]. Although the prevalence of childhood overweight and obesity has not

increased noticeably over the most recent years in Canada, it remains an important public health concern because of its serious negative impacts during adolescence and increasing the risk of associated chronic diseases and mortality [23, 24]. Childhood overweight and obesity also tend to persist into adulthood, thereby decreasing quality of life and life expectancy [25].

Given the significant role of physical activity in childhood and its important health benefits, there is a need to understand the factors that affect duration, intensity, and patterns of activity in children in order to guide research and policy for developing effective interventions to promote physical activity and prevent childhood obesity.

1.2 Study Rationale

Research to date has examined the associations of several demographic, biological, psychosocial, and behavioral factors with physical activity levels in young children [26, 27]. However, the role of the physical environment and weather is often overlooked. Of the few studies conducted earlier, most have focused on adult populations rather than children [28-30]. Meteorological attributes can have a direct or indirect effect on physical activity, and consequently on overweight and obesity in children. In each season, changes in weather, ecology, and hours of daylight can influence the duration and intensity of physical activity in all age groups [31]. Periods of low temperature, high rainfall and snowfall can reduce the likelihood of children walking or playing outdoor, and reduce the opportunities for active transport to and or from school.

In the Northern hemisphere, weather conditions can change considerably across the year and even on a daily basis, resulting in short-term variation in physical activity levels. However, children

need to be sufficiently active throughout the year, in order to benefit from enhanced fitness levels and its associated positive health outcomes. For this reason, even short periods of declined physical activity levels can be detrimental.

We live in an era that climate change is increasingly becoming a topic that warrants attention [32]. As climate change is taking place, weather patterns will be affected, and there will be more sudden and random fluctuations in temperature and rain, raising sea level, and extreme weather events such as droughts and floods [33-35]. Therefore, it demands to consider developing strategies that will accommodate higher activity levels with the changing environment. Since the weather conditions cannot be controlled or changed by humans, acquiring the knowledge on the extent that certain weather attributes affect physical activity will help to identify relevant time periods to intervene effectively and promote physical activity engagement in children. In addition, failing to consider the weather factors may compromise the findings of observational studies and result in biased assessment of physical activity levels.

1.3 Objectives

The overall objective of this thesis was to assess the relationship between weather attributes and physical activity in a large sample of school children in the Canadian province of Alberta. Specifically, the objectives were to 1) describe the demographics, socio-economic characteristics, and physical activity levels of grade 5 students in Alberta, as well as the weather attributes during the study period; 2) assess the association between weather and physical activity in grade 5 students in Alberta; 3) examine if the association between weather attributes and physical activity varies according to the day of the week (i.e. school days vs. non-school days); 4) examine if the

association between weather attributes and physical activity varies according to different time windows on a school day, including before, during and after school hours; 5) assess gender differences in the association between weather and physical activity; 6) examine if the association between weather attributes and physical activity differs according to children's compliance with daily recommendation for moderate to vigorous physical activity for this age group.

1.4 Structure of the Thesis

This thesis is written in a "monograph" format and is divided into five chapters: the first chapter is an introduction and includes an overview of the study and importance of physical activity in children, the rationale for undertaking this research and discussing the importance of studying the weather as a correlate of physical activity in children, followed by the research objectives. The second chapter is the literature review and includes a summary of the current literature on physical activity in children, its health implications, current levels and recommendations for physical activity targeting children, determinants and correlates of physical activity, and a comparison of methods used to assess activity levels. This chapter also provides an overview of the seasonality and weather trends in Canada, followed by a review of the current existing literature on the association between weather and physical activity in the Canadian context, and that outside of Canada. The third chapter, the methods, describes the study design and methodological aspects of the data used in this study, the sample of children who participated in the study, variables assessed, and the statistical analysis used to address the specific research objectives. Chapter four is the results chapter and provides a detailed description of the findings. Each section of this chapter aligns with addressing the specific research objectives of the study, and includes descriptive characteristics of the participants and their physical activity levels, findings from un-stratified

analysis of weather and physical activity data to address the second research objective, followed by findings from the stratified analysis to address research objectives 3 to 6. All tables and figures are provided at the end of the chapter, arranged in the order that they have been discussed in the text. The last chapter is the discussion and conclusion. This chapter provides a summary of the key findings of the study and their interpretation, study strengths and limitations, followed by public health implications and recommendations for future research.

1.5 Statement of Contributions

The physical activity data for this study were collected previously in 2013 as part of the Alberta Project Promoting active Living and healthy Eating (APPLE) Schools and Healthy Schools-Healthy Future (HSHF) initiative led by Dr. Paul J. Veugelers. Physical activity of the students was measured objectively using time-stamped pedometers. The weather data for this study were retrieved from the Weather Network Commercial Services (TWNC). In 2015, I proposed to study the association between weather and physical activity in children based on the information collected earlier. I contacted the TWNC to inquire about the quality of the weather data. I was responsible for developing the research objectives, writing the research proposal, and planning the analytical approach to address each of the research objectives. I was responsible for all the statistical analysis performed in this study, reviewing and summarizing the literature, and finally writing this thesis.

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Chapter II

Review of the Literature

Childhood is a critical period for the development of healthy lifestyle habits, such as regular physical activity. Developing effective interventions to promote physical activity in children requires understanding why, when and how much of physical activity is performed and what are the barriers and facilitators to physical activity in children. With this in mind, this chapter starts with outlining the importance of physical activity in children and the subsequent health implications, current levels of physical activity in Canadian children and recommended guidelines, methods used to assess activity levels, determinants and correlates of physical activity. This chapter also discusses weather as a contributing factor to physical activity and finally reviews the relevant literature on the topic in adults and in children.

2.1 Physical Activity in Children

2.1.1 Health implications

Physical activity is defined as any bodily movement produced by skeletal muscles that require energy expenditure [1]. Regular physical activity in young children has several health benefits in the short term and long term [2-4]. A recent systematic review by Janssen et al. suggested the presence of a dose-response relationship, i.e. the higher physical activity, the greater the health benefits [5]. Physical activity is known to contribute greatly to childhood development and growth [6-8], prevention of childhood overweight and obesity [5, 9, 10], optimal metabolic function [11, 12], regulation of blood glucose levels [13, 14], and blood pressure [15-17], as well as improve bone density and musculoskeletal function [18-20]. Beyond these health benefits, emerging

evidence also indicates of many psychosocial benefits of physical activity in young children and its effect on social and mental development [21, 22], improvements in self-esteem [23], reduced depression and anxiety [24], improved cognition and better academic performance [25-27], improved sleep quality and ability to concentrate [28].

Habitual physical activity in childhood tracks into adulthood, predicts higher activity levels in adults and ensures a healthier adult life [29, 30]. In longer term, potential health benefits of physical activity include reduced risk of overweight and obesity during adolescence and adulthood [31, 32], reduced risk of chronic morbidities such as type II diabetes and cardiovascular diseases [33-36], osteoporosis [5], certain types of cancer [37-39], and greater longevity [37, 40, 41].

The current state of evidence indicates that increasing trends in overweight and obesity observed over the past two decades in Canadian children and adolescents might be directly linked to the lack of sufficient physical activity [42, 43]. Nationally representative data indicates that since 1981 the body mass index (BMI) in Canadian children increased with a rate of approximately 0.1 kg/m^2; during 1981 to 1996, the prevalence of overweight increased from 15% to 35.4% in boys, and from 15% to 29.2% in girls. During the same time period, the prevalence of obesity increased by more than threefold, from 5% to 16.6% in boys and 14.6% in girls [44]. According to reports from 2007-2009 Canadian Health Measures Survey, the proportion of overweight and obesity in Canadian children was 28% and 9% respectively [45]. Although more recent estimates suggest that since 2004 overweight and obesity have likely started to decline and stabilize in Canadian children and adolescents [46], it still remains an important public health concern because of its link with chronic comorbidities [47, 48]. Childhood overweight and obesity accounts for a wide range of

psychosocial and medical consequences [49]. Obesity is considered as one of the major risk factors for non-communicable diseases, hypertension, heart diseases and diabetes [50, 51]. The problem remains of a greater concern in children, as overweight/obesity in young age tends to continue into adulthood [52, 53]. Additionally, as a result of its negative health consequences, overweight and obesity will place an added economic burden on the health-care system [54].

Theoretically, there is a direct and simple connection between physical inactivity and overweight/obesity, i.e. when energy intake is more than energy expenditure there will be a positive energy balance resulting in weight gain. Children who are less active are more prone to become overweight and obese compared to more active children of same age and gender [55, 56]. However, understanding the underlying factors that affect this balance between energy intake and expenditure is more complex [57, 58] that requires further research and evaluation.

2.1.2 Current levels and recommended guidelines

Since the 1990s, several physical activity guidelines and recommendations that specifically target children and adolescents have been developed [5, 59-61]. Although there are varying recommendations regarding the type and amount of the physical activity required for this age group [62, 63], and little attention has been given to the specific considerations such as BMI or weight status in developing the guidelines [64, 65], the general consensus is that any significant increase in physical activity levels will be beneficial in children [57, 66].

The World Health Organization (WHO) recommends that children and adolescents aged 5-17 years should engage in 60 minutes or more of daily physical activity most of which should consist of moderate to vigorous aerobic activities that result in increased heart rate [1]. Furthermore, in a

week there should be at least three days of vigorous-intensity physical activity, muscle-strengthening activities and bone-strengthening activities that include running, jumping or turning, for a minimum of 60 minutes per day. The daily minimum of 60 minutes can be achieved through multiple shorter intervals throughout the day. However, in recent years, sedentary lifestyle in children has increased across most of the developed countries, mainly as a result of technological advancements, ease of access to computer games, the internet, mobile phones, etc [57, 67-69]. This results in physical activity levels being lower than the recommended levels in many parts of the world [62, 70, 71]. In light of these associations, the American Academy of pediatrics also recommends parents to limit their children's screen time to not more than two hours per day [72].

In Canada, the first physical activity guidelines specifically targeting children and youth were developed in 2002 [66, 73, 74]. The guidelines recommended that the time spend on moderate to vigorous physical activity (MVPA) in children and youth should be increased by 30 minutes per day, regardless of their existing activity levels. The more recent Canadian Physical Activity Guidelines recommend children aged 5-17 years to accumulate at least 60 minutes of MVPA per day in order to achieve associated health benefits [75]. This is equivalent to 13,000 to 15,000 steps per day in boys and 11,000 to 12,000 steps per day in girls [76], or a daily step counts of 12,000, irrespective of gender, to assess adherence to the MVPA recommendations [77]. However, in Canada most children are not sufficiently active. Findings from 2007 to 2009 Canadian Health Measures Survey revealed low levels of physical activity among Canadian children and youth. The report states that less than 10 percent of Canadian boys and girls meet the recommended physical activity levels. The average daily step count is 12,100 in boys and 10,300 in girls. Girls were found to be less active than boys at all ages [78]. Reports from Canada's Physical Activity Levels Among

Youth (CANPLAY) Survey, that uses pedometer to measure step counts, show approximately similar estimates; children aged 5 to 19, took an average 11,200 daily steps during 2014 to 2015, with boys being more active than girls and gender differences found to be statistically significant in children aged 5 to 10 years old [79]. The report shows that although at the national level physical activity levels have remained relatively stable over the past decade, 2014-2015 rates were slightly lower than the previous years. In Alberta, the average daily steps in children and youth is approximately the same as the national average at 11,100 steps per day [79]. In terms of activity patterns, boys and younger children are more active compared to girls and the older children, those with a preference to be physically active take more steps than those who prefer sedentary activities, and those who participate in organized activities take more daily steps [80]. In September 2005, Alberta Education implemented the Daily Physical Activity (DPA) policy requiring at least 30 minutes of daily physical activity for all students in grade 1 to 9. Despite this policy, the CANPLAY provinicial report shows that between 64-86% of children and youth in Alberta do not meet the recommended activity levels, depending on which guideline criteria is used for assessment [80].

2.1.3 Measurement methods

Measurement of physical activity is necessary not only to assess the levels of physical activity, but also to evaluate the impact and effectiveness of health interventions that aim to increase physical activities and promote active living, as well as to guide future interventions [81]. The measurement methods of physical activity involve methodological and validity challenges in adults, while in children these challenges are augmented due to their "complex and multi-dimensional activity patterns"[10], as children are inherently more active than adults [82], the rate and intensity of their

activities varies extensively [83], and their activities are more likely to be intermittent rather than continuous [84]. Variation in the assessment methods may lead to inconsistencies across the studies involving physical activity. As a result, use of a reliable and accurate measure is important to accurately assess activity levels [57]. A number of different methods are available for assessment of physical activity, each having their relative advantages and limitations. These methods can be broadly grouped as subjective and objective methods according to the type of the information they provide.

Subjective methods include questionnaires in the form of diaries or activity logs, recall questionnaires, interviews or proxy-report questionnaires which are completed by parents, guardians or other caregivers [85]. Self-report and recall questionnaires are more challenging for accurate assessment of physical activity in children, as children are less time-conscious and generally have a more complex activity pattern compared to adults [83, 86]. In younger age groups, proxy-reported questionnaires may be more beneficial as they are cost-effective and less subjected to recall bias or misinterpretation [87]. Proxy-reported questionnaires have been found to provide reliable information on type, duration and frequency of physical activity in children [88]. In general, subjective methods are relatively reliable especially when used in older children. They are also in-expensive and easy to administer in a variety of settings [89]. Despite their potential to find higher activity levels as for the most part the respondents tend to over-represent their activities, introducing different forms of bias, such as recall bias or social desirability bias [90, 91] and distort the assessment of physical activity, subjective methods can be considered as a useful, practical and cost-effective method in large-scale, population based studies, or when the resources are limited [91].

Objective measures of physical activity have been recommended as an alternate method, particularly in studies involving children, as they are more likely to provide an accurate picture of daily activity levels and are less prone to introduce bias associated with subjective measures. Examples of the objective measures include doubly-labelled water measuring total energy expenditure [92], heart rate monitor, and motion sensors or motion detector devices such as pedometers and accelerometers. Among these methods, direct calorimetry, a specific form of doubly-labelled water, is considered the gold standard for objective assessment of physical activity [87]. Although this technique provides an accurate measure of energy expenditure and physical activity, it is not considered as a method of choice in children as it is invasive, expensive and cannot measure typical activity patterns among them [93]. In contrast, motion detector devices provide a relatively less expensive and more affordable method to objectively measure physical activity, and an appropriate measurement choice in children owing to their ease of use [87]. Accelerometers are usually used to record duration, intensity, frequency and the total amount of physical activity [94], whereas pedometers record step counts per unit of time and are more useful to record ambulatory activities, such as walking, running, etc [95]. They can also be used to study different patterns of physical activity when used in combination with a data memory to store information over time [85]. Although the validity and reliability of pedometers [96-98] and accelerometers [99-101] have been studied repeatedly, the main drawback with these devices remain in the fact that they need to be worn for multiple days and usually for a minimum duration of 8 to 10 hours in a day for accurate data collection [102-104]. This leads to the problem of lack of compliance in children and introducing potential measurement bias. Both accelerometers and pedometers are limited to recording ambulatory activities, therefore non-ambulatory activities, such as cycling or swimming, are not captured. Also due to safety measures, they cannot be worn

when coming in contact with water, or other high impact activities such as martial arts. This feature limits the accuracy of the information collected. Additionally, they can be expensive in large scale population-based studies. Despite these limitations, both pedometers and accelerometers have been used frequently in human studies and are commonly recommended as a method of choice for objective assessment of physical activity.

Both subjective and objective measures can provide useful information; the method of choice eventually depends on several factors, including study design, goals and objectives, the population being studied, and resources available. The choice further depends on the ease of administration and comfort when used by the individuals, and ability to make an assessment over prolonged period of time [85].

2.1.4 Determinants and correlates

Determinants of physical activity have been mainly identified through cross-sectional studies, therefore they can be considered mostly as "correlates" of physical activity rather than causal factors [105]. Physical activity is a complex behavior that can be influenced through an interplay between groups of factors at the individual and beyond the individual level, some of which may be more significant for a certain age group or at a particular developmental stage [106]. Successful and effective promotion of physical activity requires a comprehensive understanding of its correlates and determinants at multiple levels, including individual, family/peer relationships, community, and societal, such as that offered by a socio-ecological model [106, 107]. The socio-ecological model offers a theoretical framework to examine factors at multiple levels, including individual interpersonal, organizational, community and policy that contribute to physical activity

[108]. Through acknowledging multiple dimensions of physical activity and the importance of factors that lie beyond the individual level, the model thus helps to identify opportunities for effective promotion of physical activity in individuals and within communities [109, 110].

In children, physical activity is influenced by a number of factors at the child level and beyond child level. At child level, biological factors such as gender and age are among the established determinants of physical activity [111], with boys being more active than girls [76, 112, 113], and activity levels tending to decline with increasing age [111]. Other factors at child level are developmental factors such as BMI or body composition, psychological factors such as attitude, self-efficacy, perceived competence, perceived barriers to physical activity, and behavioral factors such as eating habits, sedentary behavior, and previous physical activity [114]. Changes in lifestyle and increased sedentary time as a result of accessibility to television and the internet have contributed to changes in physical activity patterns [115]. Research indicates that genetic predisposition can also play a role in acquiring physical activity habits [116], and about 72-78% of the inter-individual variation in habitual physical activity can be explained by genetics [117].

Beyond child level, research demonstrates a link between social and environmental factors [105], parental attitude and behavior regarding exercise, parental support and monitoring sedentary behaviors of their children, and ethnicity with physical activity among children [118-120]. Socioeconomic factors such as parents' level of education and household income can also affect physical activity in children; children whose parents are more educated or have a higher household income are often more active [121]. Outside family level, the school environment can be important in shaping physical activity habits in children as they spend most of their waking hours at school, and in many parts of the world schools provide structured activity programs and policies. Despite

inconsistent evidence regarding school day and non-school day activity levels, several studies have reported of higher levels of physical activity on school days [102, 122-124], and during school hours [123, 125].

More recently, studies have looked at the association between the built environment with activity levels, and findings have demonstrated an association between physical activity with the perception of safety, recreational environment, the opportunity for active transportation [126-128], and the role of other environmental determinants such as neighborhood and urban design, home and school environment [129-131]. These studies have found that environmental factors such as neighborhood safety and walkability, access to parks, fitness programs, exercise equipment and facilities, and the amount of time spent outdoor can largely influence physical activity in children and adolescents. Active transportation to and/or from school in the form of walking, cycling or use of public transport can make a significant contribution to the daily required dose of physical activity in school children as it can be achieved on a regular basis [132-135], however, it can be largely influenced by environmental factors. Lastly, evidence is emerging that indicates the associations between natural aspects of the environment, such as weather and seasonality, with physical activity in children. Despite its importance, studies in this field have received less attention and the weather has been relatively overlooked as a correlate of physical activity [136]. This relationship is the focus of the current thesis and is discussed in greater details in the following section.

2.2 Seasonality and weather trends in Canada

In Canada, climate varies widely based on geography and time of the year. Most of the economy and social activities are climate-dependent as the majority of the regions experience a wide fluctuation in seasonal temperatures and weather conditions [137]. Each year is divided into four distinct seasons: spring (March to May), summer (June to August/ early September), autumn (September to November) and winter (December to February or later). Temperature and precipitation can differ considerably between the seasons. For instance, in Edmonton while the average temperature and precipitation in March is respectively -4.4^{o}C and 16.5mm, in June it is 14.1^{o}C and 72.7mm [138]. Except for the Northern territories, most Canadian provinces are characterized by mild spring, warm summer, pleasant autumns and a very cold and long winter. Among the provinces, the prairie provinces such as Alberta and Saskatchewan are known to have more variation in their climates [139]. For this reason, the impact of weather on physical activity is expectedly more prominent in these regions.

The historical weather trends show that during the second half of 20th century (from 1950 to 1998), the southern and western parts of Canada (i.e. Saskatchewan, Alberta and British Columbia) have warmed up, while in the northeast part (i.e. Nunavut, Newfoundland and Labrador) the temperature has declined, mostly in winter and spring. Across the country, during the same period, precipitation measurement has increased between 5% to 35%, and there has been a significant negative trend in precipitation for the southern parts in winter. The ratio of snowfall to total precipitation has also increased, most significantly in southern parts and in spring [139]. In Alberta, during the past two decades, the daily average temperature has been the highest between July to August, and the lowest between January to February. During the same time, precipitation (mm) has been the highest

between July to September, and the lowest in January and February [138]. Throughout the year, the temperature can vary from 35 degrees in summer to -25 degrees or lower in winter [138]. These weather patterns suggest that we may expect certain aspects of the weather to have more influence on physical activity.

2.3 Review of literature on the association between physical activity and weather

Generally, based on available evidence and rationality, it is perceived that certain aspects of the weather can have an influence on activity levels in different populations. Variation in ambient temperature, daylight, precipitation, wind speed and other weather attributes can either promote or hinder activities in human beings. Although the growing body of evidence is showing that weather and seasonality can be a determining factor in physical activity levels, results are conflicting. This section will review some of the available evidence pertaining to the effect of weather attributes and seasonality on physical activity in adult and child populations to shed light on what is already known on this topic.

2.3.1 Studies among adults

Several studies in adult populations indicate that poor weather is perceived as a barrier to being physically active [140-144]. Togo et al. [144] studied activity levels in Japanese adults and reported that physical activity increased as temperature increased between -2 to 17 degree Celsius, but decreased with temperature increasing above 17 degrees. They also reported an exponential decrease in physical activity with an increase in precipitation. Hippel et al. [145] found that in the United States counties where winter is colder and darker, adults are less active and more obese. Among Canadian adults, evidence suggests that inactivity levels are more prevalent during winter

time compared to summer, the total average daily energy expenditure and leisure time physical activity are also higher during warmer seasons, and the associations have been found to be stronger in Prairie Provinces such as Saskatchewan and British Columbia [146]. Similarly, a study among Canadian adults from Prince Edward Island [147] reported of modest changes in physical activity levels with changes in weather. They reported a 2.9% increase in physical activity for every 10 degree Celsius increase in mean ambient temperature and a decrease between 5.2-8% with an increase in the amount of snowfall. Other factors that were found to negatively affect physical activity were the amount of snow accumulated on the ground and maximum wind speed. In contrast, a study in American adults that assessed changes in physical activity with perceived and objectively measured weather factors, found no association between any of the assessed physical activities with measured weather factors, however, they found some effect of the individual's perception of weather on physical activity. The study used self-report method to collect information on leisure time physical activity, walking and transportation activities of the participants. They used Geographic Information Systems (GIS) to create scores for weather variables including heat index, average wind chill, standard pressure, and total daily precipitation. The authors concluded that physical activity needs to be assessed against individuals' perception of their environment [148].

2.3.2 Studies among children

Studies among children have suggested that being outdoors could be a significant positive predictor of their activity levels [149-151], as generally the time spent outdoor is more actively spent than the time indoor [152, 153]. In child populations, growing body of evidence dictate that weather and seasonality can influence activities. A review by Carson and Spence have summarized

previous research on seasonality and physical activity among children and adolescents, and the authors reported that 83% of the reviewed literature showed seasonal variation in physical activity, irrespective of the study design and method used to measure physical activity [154]. Their review was based on publications available from 1980 to 2009, and the studies found were from twelve different countries, mostly European and Western countries including Canada and the United States. Studies from the North American region revealed that activity levels in children were the highest during spring and summer, and lowest during fall and winter. These observations indicate that seasonal variation in physical activity might be a result of changes in the weather attributes.

Brodersen et al. studied correlates of physical activity and sedentary behavior among 4,320 UK boys and girls aged 11-12 years old using a cross-sectional design, and demonstrated that activity levels decreased with precipitation in girls, and sedentary behavior increased with lower temperature in boys [155]. However, in their study only the frequency of vigorous exercise was measured using self-report questionnaires, which may not be an accurate measure of the actual or habitual daily activity levels. In addition, they did not compare the associations between weekday and weekends, while it is possible that the effect of weather on activity levels can be larger during weekends due to more unstructured/unplanned activities occurring. From New Zealand the study by Duncan et al. [156] showed that decreased mean ambient temperature and increased precipitation negatively affected step counts independent of day length, duration of sunshine, and wind speed in a sample of 1,115 children aged 5-12 years old. The study used a cross-sectional design, and physical activity was measured over five days using pedometers. A drawback in their study was that physical activity was not recorded for the time when children removed their pedometers, and non-ambulatory activities were not accounted for. Therefore, their assessment of

physical activity was only based on step counts recorded by pedometers. Harrison et al. studied the association between accelerometer-measured physical activity and sedentary time with rainfall during a summer school term in a sample of 1,794 British children, 9 to 10 year old [157]. This study was also based on a cross-sectional design and according to their results, rainfall was negatively associated with minutes spent on MVPA and positively associated with sedentary time. Despite the findings, a major shortcoming of their study was that unusual weather conditions were seen across the UK in the time frame of their data collection, that was characterized by above average rainfall and the month of April was reportedly the warmest on record, therefore, the findings from their study may not necessarily hold true for the population studied. Furthermore, precipitation was the only weather variable that they studied.

In Canada, a five-year longitudinal study of physical activity in 1,293 adolescents showed that over the study period physical activity was 1% to 2% higher with every 10^{o} C increase in temperature, while it was 2% to 4% lower with every 10mm increase in rainfall, and "days with snowfall had lower physical activity". In their study, physical activity was assessed every three months, using seven-day recall questionnaire [158]. The study by Lewis et al. demonstrates that the influence of weather on physical activity largely depends on the geographical location [159]. A novel aspect of Lewis et al. study was that they compared the effect of similar weather elements on MVPA and sedentary behaviors measured by accelerometer in cross-sectional samples of children between two countries with widely different climates: Australia and Canada (n= 491 in Australian and n= 524 in Canadian samples). While the temperature was positively associated with higher MVPA in Canada, it negatively affected MVPA in Australian children. They found that among the weather elements, the daily maximum temperature was the only element that was

associated with both of their outcomes in both countries. They also showed that precipitation (rainfall) was positively associated with increased sedentary time in Canadian children, and negatively associated with MVPA in Australia. The authors also pointed to the fact that how school policies shape around the climatic conditions in two countries; while in Canada some schools have policies for extreme cold weather conditions, in Australia there is a "hot weather policy" where school activities are changed or adapted when the temperature increases to a certain level [160]. In contrary to this evidence, a study among 9-11 year old girls in Vancouver, British Columbia, did not find any changes in physical activity and sedentary behavior (i.e. watching television) associated with seasonality in children. In this study, physical activity was assessed longitudinally over a 9-month academic period using self-reported questionnaires every three months [161]. A longitudinal study from Senegal in Africa reported that activity levels and corresponding daily energy expenditure were higher during rainy season (n= 30) compared to the dry season (n= 40) in rural adolescent girls; physical activity was measured using accelerometer and by direct observation methods in the two seasons [162]. It should be noted that in Africa adolescents and girls in general are considered highly active because of their lifestyles, having to contribute to daily house chores, heavier workload and other social responsibilities. Although the population in this study is widely different from the western populations, from another perspective their finding indicates that the effect of weather on activity levels is not an unambiguous relation, rather there are other demographic factors such as culture and lifestyle that can change the direction of this association.

From the reviewed literature, it appears that in studying the associations between weather and physical activity, a number of research gaps exist. Despite the existing evidence, the role of other

modifying factors has often been overlooked. For example, gender differences in the effect of weather on activity levels remain inconsistent across the literature, and potential differences between weekdays and weekends have not been thoroughly investigated. There is paucity of literature studying the within day variation in physical activity based on weather conditions, such as the varying effect of specific weather attributes during different time windows in a day. Acquiring this knowledge will have important implications in the design and development of public health policies and programs to promote active living and active transport in children and consequently to contribute to higher activity levels. Furthermore, a gap persists in considering specific factors such as the effect of existing activity levels of children, in the association between weather and physical activity.

Lastly, this chapter is concluded by noting that despite the gaps in the literature and conflicting reports in adults and children studies, and while more research is required to clearly assess the impact of weather elements on physical activity in children, what is known based on the available evidence is compelling.

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Chapter III

Methodology

3.1 Data Source

This study is based on data available from two provincial school-based programs among grade 5 students: the first, the Alberta Project Promoting active Living and healthy Eating (APPLE) Schools, initially started in 2008 as an intervention program in 10 schools in Alberta that were mostly located in socio-economically disadvantaged neighborhoods and were in need of health promotion. The primary goal of the APPLE Schools was to promote healthy living habits in children and to increase the knowledge about healthy living for the whole school community through Comprehensive School Health (CSH) approach, which is a multidimensional approach that involves parents, school communities and stakeholders to empower the whole school community for supporting and promoting healthy living in children [1]. In subsequent years, the APPLE Schools recruited additional samples of grade 5 students in the spring of each year, at present the program is implemented in 63 schools across Northern Alberta

The second, the Healthy Schools-Healthy Future (HSHF) program that started in March 2012 in 17 rural and diverse school communities as a part of the The Raising healthy Eating and Active Living (REAL) Kids Alberta survey [2, 3]. The HSHF program was also based on the CSH approach with the aim to improve healthy behaviors of school aged children and to empower schools to become a health promoting community [2, 4]. Details of the programs can be found on their websites (http://www.appleschools.ca/; http://www.realkidsalberta.ca/).

To examine the effectiveness of their interventions, the APPLE Schools and the HSHF programs collected information on physical activity levels, anthropometric measurements, diet quality, parental opinion and support, socio-economic backgrounds, and information on the school environment, programs, and practices, through a home survey, a student survey, and a principal survey. The home survey was distributed to parents of grade 5 students through which they provided their informed consent for their child to participate in the study and also to collect information on their educational attainment, household income, and their awareness and support of school health-related policies and programs. The student survey was administered to grade 5 students during school hours by two trained evaluation assistants to ensure accurate collection of data. The student survey included the Harvard Food Frequency Questionnaire for Youth and Children, a survey to assess their nutritional behavior, knowledge, attitude and self-reported physical activities. The principal survey collected information on each school's environment, health-related programs, implementation of the comprehensive school health and provincial programs. Data collection tools and questionnaires were updated annually based on findings from previous year's research and feedback from the REAL Kids Alberta academic advisory committee.

The present study is based on data collected in 2013 in which all 43 schools from the APPLE Schools program and all 17 schools from the HSHF program agreed to participate. These schools were located in the city of Edmonton and surrounding areas [2, 5]. Within each school, all grade 5 students were invited to participate. In addition to the information mentioned above, the 2013 wave of data collection included objective assessment of physical activity by pedometer, details of which are explained in the following sections.

3.2 Ethical Considerations

Ethical approval was obtained for the original studies from the Human Research Ethics Board (REB) of the University of Alberta under the study identification number Pro00003800 for APPLE Schools, Pro00033375 for HSHF schools, and Pro0003799 for REAL Kids Alberta survey. All the students and parents who participated in the study were provided with written information about the evaluation process and were asked to provide their consents voluntarily. Only the students whose parents provided their written consent were asked to participate in the surveys. All participants' information is kept confidential and none of the publications or public presentations contains any information about the participants, their families or name of their schools and districts. All employees involved with this research were also asked to sign a memorandum of understanding to ensure data confidentiality.

3.3 Study Participants

A total of 60 schools in Alberta were included in the 2013 wave of data collection. We distributed 2,321 home surveys to parents to obtain informed consent for their grade 5 child to participate in the study (Figure 3.1). A total of 1,768 surveys (i.e. response rate of 76.2%) were returned with 1,672 parents giving their consent (i.e. consent rate of 94.6%). The target population in this study was grade 5 students (boys and girls), aged 10 to 11 years attending elementary school. Grade 5 students were recruited because children in this age group have adequate literacy level that enables them to respond more accurately to the questions compared to their younger peers [6]. Additionally, in Alberta all grade 6 students are required to take a provincial exam and the participating schools preferred not to involve those students in order to not distract them from their studies due to data collection.

Among the students whose parents granted their consent, a total of 1,635 students assented to participate and completed the student survey (i.e. survey completion rate of 97.8%). The overall parent consent, student consent, and survey completion rate was 92.5%. The main reason for not participating was that either the students were absent from school at the time of the data collection or their parents did not provide consent.

3.4 Assessment of Physical Activity

The outcome in this study was physical activity defined as the number of steps per hour measured objectively using the Omron HJ-720 ITC time-stamped pedometer that has a precision of ±5% (crude step count) [7]. Several studies have established the reliability and validity of Omron pedometer in objective assessment of physical activity [8-10]. This type of pedometer has a convenient memory function, as data from each day is automatically stored in the memory and time is automatically reset at 12:00 am. This feature allowed its easy administration by the participants [11]. The device stores data for up-to 41 days and it can display the most recent 7 days of recorded data. The students were instructed to wear the pedometer on their right hip directly in line with their right knee for 9 consecutive days during all waking hours except when showering, swimming or participating in high impact sports and activities due to safety regulations. Due to differing administration and collection times, the first and last day of pedometer records were not included in the analysis. This resulted in 7 full days of physical activity data for each participant.

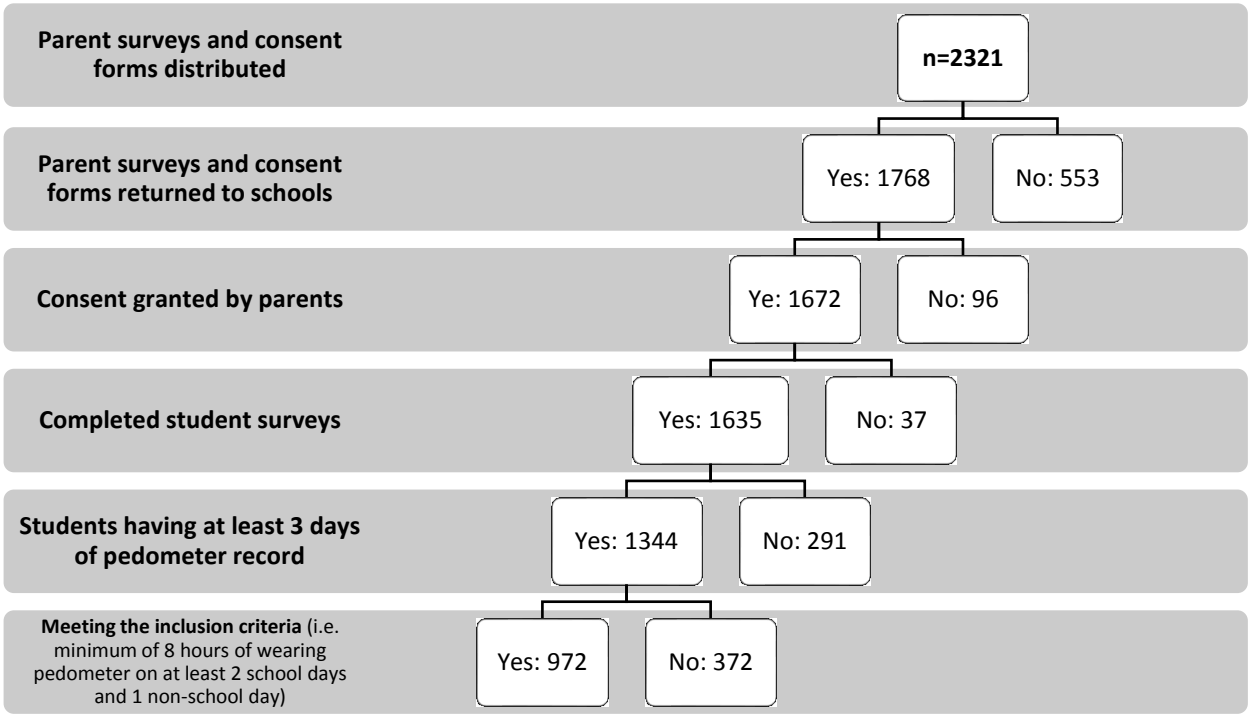

Figure 3.1. Enrollment of study participants and the inclusion criteria in the present study

Recorded physical activity data from pedometers were considered valid and complete if the students wore a pedometer for a minimum of 8 hours per day [12], and for at least two school days (i.e. Monday-Friday) and one non-school day (i.e. Saturday, Sunday and holidays) [13]. Daily step counts of less than 1000 or more than 30,000 were considered as outliers and were excluded from the analysis [14]. In addition, students were asked to complete a 7 day activity log (pedometer activity dairy) during the same period, and to record the type and duration of any activities that they participated in and whether or not they were wearing the pedometer during those activities (Appendix D). On the third day of data collection, evaluation assistants returned to the schools to remind and encourage students to wear their pedometers and to complete their activity logs. On the ninth day, pedometers and activity logs were collected from the schools by the evaluation assistants and data were downloaded to a computer. A total of 1,344 students had recorded physical

activity data for at least three days, and a total of 972 students met the minimum of 8 hours criteria for two school days and one non-school day and therefore were eligible to be included in the analysis (Figure 3.1).

The information collected through students' daily activity logs were used to adjust for the crude pedometer measured steps by estimating the step counts accumulated through activities during which pedometers were not worn, such as swimming and skiing [11]. To achieve this, Youth-specific Metabolic Equivalent Task (MET) units were assigned to each activity in student's log record [15]. Based on assigned MET unit, activities were categorized into moderate (0-3 MET), moderate-vigorous (3.1-5.9 MET), and vigorous (6.0-8.9) categories [16, 17]. Adult MET units were used whenever youth-specific values were not available [16]. Next, steps per minute values were assigned to each category [15], and based on National Association of Sport and Physical Education (NASPE) guideline that 15 minutes of physical activity in children is comprised of 10 minutes of activity with 5 minutes of rest in between, steps per minute values for each physical activity category were multiplied to two-thirds of the duration of the activity reported by the students in their activity log to estimate the step counts achieved during that activity [18]. The step counts obtained through this method were referred to as "log-adjusted steps". For the days that students forgot to wear their pedometer and record their activities, missing data was imputed from other randomly selected days for which pedometer data was available for that individual [11].

3.5 Assessment of Weather

Meteorological data were obtained from the publicly accessible weather information data feed through the Weather Network Commercial Services (TWNCS). The weather Network is a North

American-based company that provides weather-related information and services. Their weather data is based on information collected by local weather stations run by the Environment Canada, as well as a virtual observation weather data feed which is based on an estimate of current atmospheric conditions derived from multiple data sources. These data sources include traditional surface weather stations (in-situ), instruments that remotely sense the atmosphere such as radar and satellite, and other sources which describe general atmospheric conditions such as climatology and numerical weather prediction models. The virtual observation weather data-feed provides a more complete coverage of the weather conditions and is considered to be more accurate than the real observations [19].

The data for this study included 24-hourly weather information for the time frame between March to June 2013, for twenty three sites across Alberta where the schools were located (Table A in Appendix). The specific weather attributes used in this study were hourly actual temperature, hourly "feels-like" temperature, hourly cloud coverage in the sky, daily maximum, daily minimum temperature, and the total amount of precipitation in a day. The temperature was reported in Celsius. Daily maximum temperature refers to the highest temperature recorded in a 24-hour period ending in the morning of the next day. The daily minimum temperature is for a period of the same length, beginning in the evening of the previous day [20]. Cloud coverage is generally reported as the amount of sky in tenths that is observed to be covered by layers of cloud (on a scale of 0 to 10 with 0 being a clear sky and 10 being overcast) [20]. The daily precipitation measurement reported refers to the water equivalent to all types of precipitation, including rainfall and snowfall reported in millimeter (mm). Precipitation is usually measured using the standard Canadian rain gauge, which is a cylindrical container 40 cm high and 11.3 cm in diameter [21].

During the study period, a total of five days had missing weather information for all 23 regions, due to problems with archiving at The Weather Network Services. For the days with missing data, information on weather attributes was imputed based on data available for the two adjacent days. For instance, data was missing for March 20; I used averages of weather attributes recorded on March 19 and March 21 to impute data for the missing day.

3.6 Assessment of the Covariates

Participants' gender was self-reported. Height and weight measurements were taken by trained evaluation assistants following student's assent. Students were asked to take off their shoes before measurements. Height was measured to the nearest 0.1 centimeters using stadiometer and body weight was measured to the nearest 0.1 kilograms on calibrated weighting digital scale. BMI was calculated as weight (in kilograms) divided by height squared (in cm). Z-scores for BMI were calculated based on WHO LMS method [22, 23], and weight status was categorized to normal, overweight and obese categories based on WHO's age and sex specific z-score cut-offs in children [24, 25]. Information was collected on parental educational attainment (secondary school or less, college diploma, and university or graduate school), and household income ($50,000 or less, $50,000-100,000, and more than $100,000) through home surveys completed by students' parents/guardians. Weekdays were categorized to school days (Monday-Friday) and non-school days (Saturday, Sunday and holidays). School regions were categorized to rural, urban and metropolitan based on the Statistics Canada's classification of the census areas (available from: https://en.wikipedia.org/wiki/Statistics_Canada).

These variables were considered as covariates of interest because of their independent importance on varying levels of physical activity in children. Available evidence suggests that physical activity might vary by gender, and boys are inherently more active than girls [26-28]. Socio-economic factors such as household income and parental education might also influence physical activity in children [26, 29]. In Canada, national data indicates that children from households with higher income or more educated parents are more active [30]. Moreover, research suggest of variation in physical activity levels by school days and non-school days [11, 31, 32].

3.7 Statistical Analysis

Physical activity and weather data collected between 7:00 am to 8:59 pm were considered for analysis in the present study, as outside this time period, children tend to be less active or inactive, therefore, weather conditions are unlikely to have an effect on children's physical activity beyond this time frame [33-35]. Days were used as unit of analysis to assess day to day variation in physical activity within children. The primary outcome of the study was the total number of steps per day and the total number of steps per hour (continuous variables). All weather attributes were treated as continuous variables in the analysis, with the exception of precipitation. Due to its highly skewed distribution, precipitation was categorized into none (0 mm/day), light (0.01-5 mm/day) and heavy precipitation (>5mm/day). Due to the nature of data obtained on precipitation, in all analyses precipitation refers to both rainfall and snowfall depending on the month of study, as typically in March most of the precipitation is in the form of snow, whereas in June it is mostly rain or drizzle. Seventy eight millimeter of precipitation was recorded on May 25th, 2013, based on the Canadian Climate Normals this measurement is not typical of this month [21]. Therefore, because of its extreme value it was considered as an outlier and observations from that day were removed before analyzing the data.

Exploratory analysis was performed to check the assumptions for conducting a regression analysis [36]. Normality distribution of physical activity was checked using histogram; step counts less than 1,000 and more than 30,000 per day were considered as outlying observations and were removed from the data [14]. Normality assumption of the weather attributes was also checked using histograms and box plot to detect any outliers and unusual observations. Linearity of the predictors were checked using Lowess smoothing curve [37]. Weather data obtained for each of the schools over a week was combined with the physical activity data of all students within that school for the same time period. Identification numbers were assigned to each person and each school for combining the data. Time was numbered as 7 to 21 (representing 7:00am to 8:59pm), date were entered as day/month/year format, and month was assigned numbers 1 to 4 (1=March, 2=April, 3=May, and 4=June). Weather and step counts data were matched for time, date and month of the observations.

Descriptive statistics are reported as mean ± standard deviations and frequencies. Student's t-test was used to assess mean differences in step count between boys and girls, and to assess mean difference in step count on school days and non-school days. Pearson Chi-square test was used to assess gender differences in weight status, parental income, and education. Scatter plots were used to display the distribution of weather attributes individually and in relationship to physical activity.

Multi-level mixed effect modeling was used to assess the relationship between weather attributes and physical activity. This method was selected to adjust for the clustering effect of students within schools, and the schools located within the same region of weather data collected [38]. It also

ensures greater accuracy than ordinary linear regression when dealing with repeated measures [39]. In all models, the random effects (random intercepts) were weather region variance (23 sites across Alberta), school variance (60 schools) and between subject variance (total of 972 individuals) to adjust for these variables (Figure 3.2). Hausman test was used to select between fixed effect and random effect for other independent variables. A significant test (p-value<0.05) suggests that the variable should be included as fixed effect in the model [40]. Based on Hausman test p-value and to assess the net effect of the weather attributes on the outcome, student's gender, weight status, parent's income, parent's education, and school regions (rural, urban metropolitan), and day of the week (school day vs. non-school day) were included as fixed effect covariates owing to their time-invariant characteristic. Controlling for these variables ensures un-biased estimates of the association. A random intercept was included with repeated term for each child to adjust for day to day variation in physical activity measures within individuals, as theoretically day to day variation in physical activity might influence the relationship between weather and physical activity. Linearity was assessed in the association between outcome with each weather attribute, all relationships were linear, therefore we did not fit any quadratic terms [41]. I did not adjust for age as all children were selected from the same grade and age did not differ much.

To address objectives 3 to 6, analysis was stratified by day type (school day vs. non-school day), time windows on a school day (before, during and after school hours), gender of the students, and their level of activity to assess any effect modification that they might have on the association between weather and physical activity.

To address the research objectives, univariable/unadjusted analysis was performed first with each of the weather attributes entered one at a time as fixed effect, followed by separate multivariable

analysis for each weather attribute (not mutually adjusted), and parsimonious analysis to assess the independent effect of weather attributes (mutually adjusted). The parsimonious model was based on purposeful selection method and included all weather attributes that were found to be statistically significant at <0.2 level of significance in the univariable analysis. In the final step of each analysis, associations were considered statistically significant at <0.05 level of significance. All multivaraible models were adjusted for the covariates in the study (participant's gender, weight status, parent's income and education, school region, and day of the week), except when stratifying the analysis by each of the covariates discussed. Missing values of covariates were considered as separate categories in regression models, however, the estimates are not presented for those categories.

To assess the relation between weather and physical activity based on activity levels in children, I used the 12,000 daily step cutoff that has been shown to provide a more accurate population estimate of target step count for meeting the recommended 60 minutes of MVPA in children, with more balanced sensitivity and specificity compared to other recommended cutoffs [42]. Children having ≥12,000 steps/day were categorized as "meeting" the MVPA recommendations (more active), and those with <12,000 steps per day were categorized as "not meeting" the recommendations (less active). Lastly, Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used to select the model with the best fit at each step. Model fit and distribution of the residuals were assessed using normal probability plot or normal quantile plot (qnorm) at the end of each step of the analysis [43]. All analysis was performed using STATA version 13.

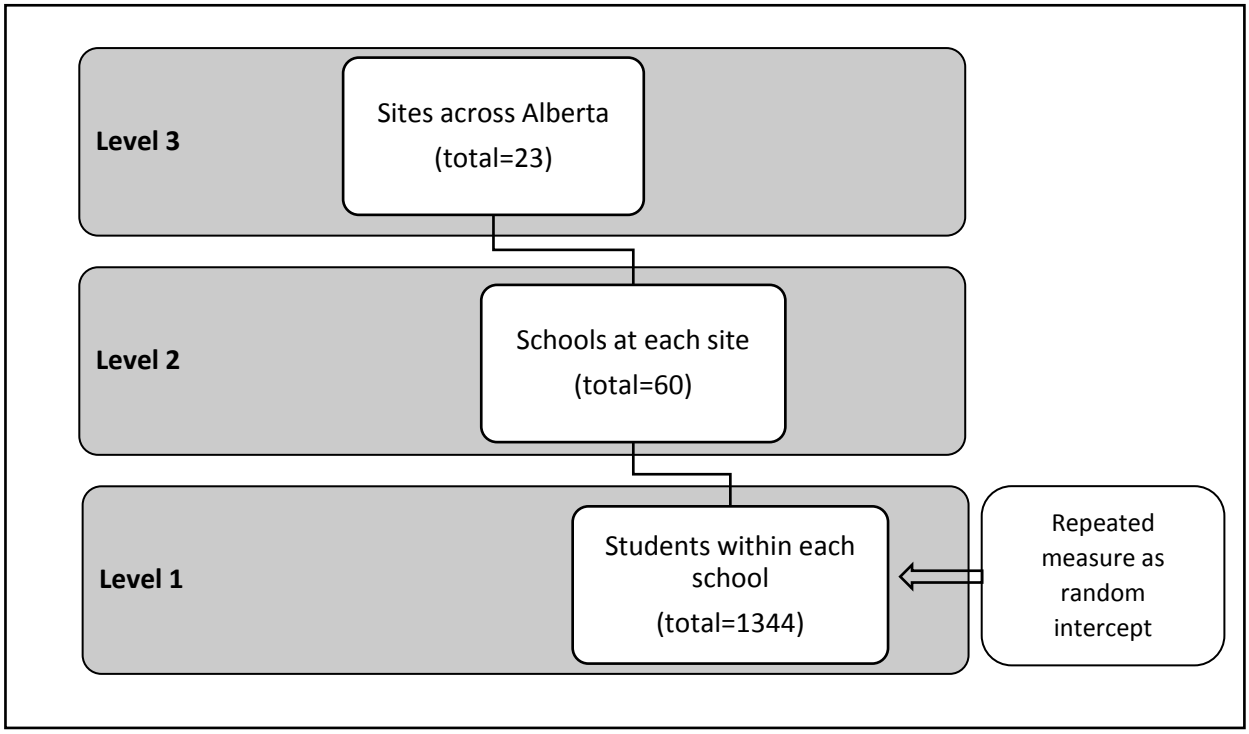

Figure 3.2. Multilevel modeling including three levels to adjust for the clustering effect of the schools located within study sites, and students within schools.

Notes: Predictor variables at individual level were: gender of the study participants (self-reported in the student survey), weight status was categorized based on the WHO age and sex-specific BMI cutoffs, adjusted for specific age and sex categories in children [24], parent's level of education (secondary or less, college diploma, university or graduate), and current annual household income (≤$50,000; $50,001-75,000; $75,001-100,000; and ≥$100,000) self-reported in the home survey, and school regions (urban, rural and metropolitan). These variables were used as a proxy for the socioeconomic status of the study participants.

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Chapter IV

Results

4.1. Addressing Research Objective 1

4.1.1. Participants Characteristics

In total, 972 students (562 girls and 392 boys) had valid physical activity data of wearing a pedometer for a minimum of 8 hours per day for at least two school days (Monday-Friday) and one non-school day (Saturday, Sunday and holidays), and were included in the analysis. Table 4.1 presents the descriptive statistics for all students who were included in the analysis. Out of three school regions (rural, urban and metropolitan), the majority of the students attended schools located within urban areas (53%). Students attending schools within metropolitan and rural areas were 35% and 12% respectively. Approximately 57.8% of participants were girls (n=562) and 40.3% were boys (n=392). The average age of the sample was 10.9 years (SD=0.4), with boys (10.9 year ± 0.4) being slightly older than girls (10.8 years ±0.4). The BMI was slightly higher in boys compared to girls (average BMI 20.2±4.5 in boys vs. 19.4±4 in girls, p-value <0.001). Z-scores for BMI were calculated based on WHO LMS method [1, 2] and the weight status was categorized according to WHO's age and sex specific z-score cut-offs in children [3, 4]. Weight status was significantly different between boys and girls (Pearson chi-square p-value=0.003). The majority (54.2%) of the students were in the normal weight category. Proportion of overweight was almost similar in boys and girls; however, obesity was significantly higher among boys (30% boys vs. 19.5% girls were classified as obese, p-value <0.05).

Information on parent's education attainment and household income was collected as socio-economic proxy indicators. Overall 37% of students' parents were university graduates and approximately half of them (49.5%) belonged to highest income category of ≥ $100,000 per annum. The proportion of parental education and household income differed significantly between boys and girls; girls were more likely to have a parent with a university or graduate degree (38% vs. 36%, Pearson chi-square p-value=0.035), while boys were more likely to come from the highest income category household (52% in boys vs. 47.5% in girls, Pearson chi-square p-value=0.04).

4.1.2. Physical Activity Levels

Physical activity was recorded daily as number of steps per hour. From all 972 students, a total of 5,958 valid days (i.e. wearing a pedometer for a minimum of 8 consecutive hours/ day on at least two school days and one non-school day) were included in the analysis, with 18.1% of observations in March (1080 days), 39.8% in April (2370 days), 31.0% in May (1842 days) and 11.2% in June (666 days). Based on the study's inclusion criteria, each individual had between 3 to 7 days of valid physical activity data. Among the participants, 461 individuals (47.4%) had seven complete days of recorded physical activity. The average duration of wearing a pedometer was 14 hours per day (SD=2.42), and the duration ranged between 8 to 18 hours per day. Data collected between 7:00am to 8:59pm were considered for the analysis, as accumulating steps beyond these hours is generally unlikely for this age group [5].

Table 4.1 shows summary statistics (mean and standard deviations) for physical activity based on steps recorded per day and steps recorded per hour, and for school days and non-school days. For the entire sample, the average number of steps per day in a typical week of 5 school days and 2 non-school days was 11,011 (± 5751) and the average number of steps per hour was 734 (± 914).

The average daily physical activity was significantly different between boys and girls, with boys taking 1476 more steps per day than girls (mean steps/day was 11,889 ± 6453 in boys vs. 10,413 ± 5135 in girls, p-value<0.001). Similarly, the average number of steps per hour was significantly higher in boys compared to girls, with a mean difference of 98 steps per hour (mean steps/hour was 792±997 in boys vs. 694±851 in girls, p-value<0.001).

Children engaged in more physical activity on school days compared to non-school days (mean steps/day 11,483±5008 on school days vs. 9,953±6974 on non-school days, p-value<0.001). Physical activity remained significantly higher in boys compared to girls on both day types (p-value<0.001 for school days and p-value=0.005 for non-school days). Variation in physical activity levels between school days and non-school days can be further observed in Figure 4.3. The figure shows activity levels during windows of time between 7:00am to 8:59pm across boys and girls on school days and non-school days. The bars at each time point illustrate the average number of steps accumulated during the previous time window. For example, the bar at 8:00am corresponds to the average number of steps accumulated between 7:00am to 8:00am. As can be seen, the average steps per hour was generally higher on school days (Monday-Friday), and boys consistently had higher activity levels than girls at all time points during the day except at 8:59pm were girls had slightly higher mean steps. Additionally, the difference between boys and girls was less pronounced on non-school days (Saturday, Sunday and holidays).

Lastly, students were categorized according to their compliance with recommendations for 60 minutes of MVPA in children which is approximately equivalent to 12,000 steps per day or more [6]. Descriptive statistics (Table 4.1) showed that the proportion of students meeting the MVPA recommendation was higher on school days compared to non-school days (40% and 30%

respectively). Compared to girls, more boys met the recommendations on both day types (recommendations met by 48% of boys and 34% of girls on school days, and 33% of boys and 29% of girls on non-school days, chi-square p-value<0.001).

4.1.3. Weather Attributes

Weather data for Alberta in 2013 obtained from The Weather Network Commercial Services (TWNCS) was also analyzed for windows of time between 7:00am to 8:59pm to match the physical activity data. Data included information on actual temperature, feels-like temperature, daily maximum and minimum temperature, cloud coverage (ranging between 0 to 10 corresponding to the least and the most cloud coverage), and total precipitation (in mm) measured in a day. Figure 4.4 and Table 4.2 depict variation in daily average weather attributes by month between March to June 2013. The mean ambient temperature varied significantly between months of observation (p-value of F-test statistics <0.01). The temperature gradually increased from the first month of the study (March) to the last month (June), with a mean difference of 25^{o}C (p-value<0.05). The average temperature in March was -12 ± 5.7^{o}C and it typically remained below 0^{o}C with the lowest of -28^{o}C and the highest of 7^{o}C. In April, the average temperature was 1.0^{o}C (±5.3), minimum and maximum temperatures were -14^{o}C and 20^{o}C respectively. In the month of May, the average temperature was 12^{o}C (±6.5) with minimum and maximum of -5^{o}C and 30^{o}C respectively. The average temperature in the month of June was 14.6 ± 3.6^{o}C, with the minimum and maximum temperatures of 7^{o}C and 24^{o}C, respectively.

Cloud coverage and total precipitation did not show a particular seasonal trend. Though both of these weather attributes were significantly different between the months of study (p-value of F-test statistics <0.01 for cloud coverage and chi-square p-value <0.001 for precipitation). Cloud coverage

is generally reported as the amount of sky in tenths that is observed to be covered by layers of cloud, on a scale of 0 to 10 with 0 being clear sky and 10 being overcast [7]. The average cloud coverage was the highest in March (6.4±4.3) and April (6.2±4), and it was the lowest in May (4.6±3.3) and June (5.0±3.6).

The amount of daily precipitation was generally zero or near zero millimeters over the study period (Figure 4.4). Light precipitation (0.01-5 mm per day) occurred on 33.6% of days of study period in March, 23.7% of days in April, 9% of days in May and 27% of days in June. Heavy precipitation (more than 5 mm per day) occurred only on 1-2% of days in March and April, but more in May and June (12.7% and 19% of days of observation in May and June respectively). The highest amount of precipitation reported was 78 millimeter that occurred on May 25th, 2013, due to its extreme value it was considered as an outlier and observations for that date were removed from the analysis. In June, the highest amount of precipitation was 26.4 millimeter which was recorded on June 12th.

4.2. Addressing Research Objective 2

Association between Weather Attributes and Physical Activity

Table 4.3 presents the results of linear mixed-effect regression analysis showing the associations between total number of steps accumulated per day and weather attributes. The univariable model shows the unadjusted estimates of associations between physical activity and the weather attributes (derived from a separate model for each weather attribute), as well as the associations between physical activity and other covariates of interest in the study (ie. Gender, weight status, and socioeconomic factors). The multivariable model represents the estimates after adjusting the model for gender, weight status, household income, parent's education attainment, day of the week and

school region. The parsimonious model presents the adjusted independent association of the weather attributes with daily average physical activity that were included in the model based on their statistical significance while considering all other covariates of interest.

Temperature

The univariable analysis (Table 4.3) showed a positive association between mean daily actual and feels-like temperature with total number of steps per day (β=15 and 23 steps/day respectively for every degree Celsius increase in mean actual and feels-like temperature), although the associations were not statistically significant (p-value>0.05). The daily maximum temperature was positively associated with steps per day, although the statistical significance was borderline (β=26, p-value=0.052). The daily minimum temperature was negatively associated with steps per day (β=-25, p-value=0.07). The net effect of average feels-like temperature was significant in multivariable model, i.e. for every one degree Celsius increase in mean feels-like temperature, physical activity in this sample increased by 24 steps per day independent of gender, weight status, school day/non-school day, and other socioeconomic factors. Figure 4.5 illustrates the relationship between average daily temperature and step counts across the study period (March to June), showing that physical activity was fluctuating with changes in ambient temperature.

Cloud coverage

Physical activity in children was negatively related to the mean daily cloud coverage and the relationship remained statistically significant in all three models (p-value<0.05, Table 4.3). In the multivariable analysis, the independent effect of every unit increase in the daily average cloud coverage was 61 fewer steps per day in children (p-value<0.01). When mutually adjusted for other

weather attributes, the negative effect of cloud coverage decreased by 16 steps compared to the multivariable model (β= -45, p-value<0.05).

Precipitation

In general, daily total precipitation had the largest significant effect on activity in this sample of grade 5 students (Table 4.3). Compared to no precipitation, light precipitation (0.01-5mm) resulted in 556 fewer steps per day (p-value<0.05), and heavy precipitation (>5mm) resulted in 957 fewer steps per day (p-value <0.05) in univariable analysis. In the parsimonious model precipitation and cloud coverage were the only weather attributes that showed significant association with physical activity. The effect of heavy precipitation decreased slightly compared to the univariable and the multivariable models, however, it still remained significantly associated with daily physical activity. There was 888 decreased steps per day with heavy precipitation, independent of gender, weight status and other socioeconomic factors (p-value<0.001, Table 4.3).

Additionally, the parsimonious model (Table 4.3) revealed that boys were more active compared to girls (+1627, p-value<0.01), overweight and obese children were less active compared to the children in the normal weight category (-593 steps/day in overweight, and -1234 steps/day in obese, p-value<0.01), and physical activity was higher on school days compared to non-school days (+1398, p-value<0.05), independent of the effect of cloud coverage and daily precipitation. Figure 4.6 presents the estimates of the associations between weather attributes and other covariates with the daily step counts, deriving from the model with mutually adjusted weather attribute.

4.3. Addressing Research Objective 3

Associations between Weather Attributes and Physical Activity by School vs. Non-School Days

Descriptive statistics and assessment of the sample suggested that physical activity levels varied according to the school day/non-school day (Figure 4.3). To assess the effect modification of day type on the relationship between weather and physical activity, stratified analysis was performed based on schools and non-school days. Table 4.4 presents the univariable, multivariable and parsimonious estimates derived from the stratified analysis.

Univariable model

In univariable analysis, among the weather attributes daily average temperature (actual and feels-like), daily maximum temperature and daily total precipitation had a significant relationship with children's physical activity on school days. On non-school days, average temperature (actual and feels-like), average cloud coverage and total daily precipitation were significantly associated with physical activity. Among the covariates, gender of the students and their weight status were also significantly associated with activity levels on both school and non-school days.

Multivariable model

The association between weather attributes and steps per day was larger on non-school days compared to the school days (Table 4.4). Daily average temperature was consistently related to higher physical activity on both school and non-school days. With every degree Celsius increase in daily average actual and feels-like temperature, physical activity increased respectively by 35 and 38 steps per day on school days, whereas it increased by 65 and 60 steps per day on Saturday, Sunday, and/or other holidays after adjusting the model for other covariates in the study (p-values< 0.05, Table 4.4). The daily maximum and minimum temperature were also positively related to higher activity levels on both school days and non-school days, though the association was significant association only on non-school days. The positive effect of a unit increase in daily

minimum temperature was more pronounced on non-school days (+130 steps/day on non-school days vs. +6 steps/day on school days with every ^{o}C increase in recorded daily minimum temperature, p-value<0.05 for non-school days), and the association differed significantly between school and non-school days.

In contrast, daily average cloud coverage and the amount of precipitation accumulated in a day had negative effects on daily activity levels. On non-school days, children took 170 fewer steps per day with every unit increase in average amount of cloud coverage, after adjusting for other covariates (p-value <0.01). This association was much smaller on school days (-12 steps/day) in the adjusted analysis (p-value>0.05). The effect of cloud coverage on the daily activity levels was significantly different between school and non-school days. Similarly, the number of steps per day decreased significantly with the amount of precipitation on both school and non-school days. Compared to no precipitation, light precipitation was associated with 423 fewer daily steps on school days (p-value<0.05) and 232 fewer daily steps on non-school days (p-value>0.05). Heavy precipitation was associated with 663 fewer daily steps on school days and 2427 fewer steps per day on non-school days, with statistically significant different relations based on school/non-school days. Figure 4.7 further illustrates the average daily physical activity by school and non-school day and by different categories of precipitation. This figure shows that as the amount of precipitation increases, physical activity declines. With no precipitation, the range of the physical activity is larger on non-school days. With heavy amount of precipitation, decline in average daily physical activity is more obvious on non-school days.

Parsimonious model

When the weather attributes were mutually adjusted (Table 4.4), precipitation showed negative association with activity levels on school days only (-402 steps/day with light precipitation and -613 steps/day with heavy precipitation, p-value<0.05). Additionally, feels-like temperature was significantly associated with higher step counts independent of the effect of precipitation and other covariates in the model (+33 steps/day, p-value<0.05). Conversely, the parsimonious model for non-school days showed significant positive association of physical activity with daily minimum temperature and negative association with average cloud coverage (p-values<0.05).

4.4. Addressing Research Objective 4

Association between Weather and Physical Activity by Different Time Periods on School Days

Analysis was performed based on hourly step counts between 7:00am and 8:59pm on school days. As evident from the literature, physical activity in school aged children tends to vary during a day [5]. Therefore, to assess the difference in the association between the weather attributes and physical activity by time of the day, analyses were stratified by three time periods on school days: before school (7:00am to 7:59am), during school (8:00am to 3:59pm), and after school (4:00 pm to 8:59 pm) hours. For these analyses, hourly step counts were used in the model. One-way ANOVA test was used to compare the mean weather attributes between time periods; mean temperature and mean cloud coverage were significantly different between the three time periods (oneway test p-value<0.001).

Table 4.5 presents the findings of mixed effect linear regression. For each time period, univariable analysis was performed first with each weather attribute entered into the model separately, followed by multivariable analysis adjusted for gender, weight status, household income, parent's education,

and school regions. The parsimonious model included all statistically significant weather attributes based on univariable analysis.

In general, weather attributes were most strongly associated with hourly physical activity after school hours (between 4:00pm to 8:59pm). Actual and feels-like temperature were found to be significantly associated with increase in physical activity during school hours (+2 and +3 steps per hour with every degree Celsius increase in actual and feels-like temperature respectively, p-value<0.05), and decline in physical activity after school hours (-13 and -8 steps per hour with every degree Celsius increase in actual and feels-like temperature respectively, p-value<0.05). Daily maximum temperature had a trivial but positive association with hourly steps during all three time periods, although the associations were not statistically significant in multivariable models for before and during school hours. Daily minimum temperature, on the other hand had a negative effect on physical activity before school (-8 steps/hour, p-value<0.05), and positive effect after school (+5 steps/hour, p-value<0.05). Although the latter two attributes may not reflect changes in hourly step counts accurately, as daily maximum and minimum temperatures are typically recorded at the end of the day (explained in chapter III), therefore their association with hourly step counts at different times of a day may not be meaningful.

Cloud coverage and precipitation had negative relation to hourly steps during all periods. The negative relation of cloud coverage with hourly step counts was similar across time periods, although the association was only significant after school hours (-4 steps/hour with every unit increase in cloud coverage, p-value<0.05). Precipitation also affected physical activity negatively mostly after school hours (p-value<0.01, Table 4.5).

Further, the analysis revealed that students' gender and weight status affected their hourly step counts significantly. Hourly step counts were significantly higher in boys during all time periods on a school day (p-value<0.01); overweight and obese children had fewer steps per hour compared to normal weight children (p-value<0.01), independent of weather and other attributes. Lastly, school region had a significant association with step counts after school hours. Compared to rural regions, children attending schools located in urban and metropolitan regions were significantly less active (-210 steps/hour in urban regions, -192 steps/hour in metropolitan regions).

4.5. Addressing Research Objective 5

Associations between Weather Attributes and Physical Activity by Student Gender

In this sample the number of girls was higher than boys (n=562 girls, n=392 boys). To control for the potential effect modification of gender, analyses were stratified by gender of the students and effect modification on each of the weather-related attributes in relationship to physical activity was assessed (Table 4.6).

Univariable model

In the present study, weather had a larger association with physical activity among girls compared to boys. In univariable analysis, the effect of every degree Celsius increase in the average daily temperature corresponded to an additional 46 steps per day in girls (p-value<0.05) compared to an additional 18 steps per day in boys (p-value>0.05). In girls, with the exception of daily minimum temperature, all other weather attributes were significantly associated with their step counts, whereas in boys, the only significant associations were found for daily average cloud coverage and daily total precipitation. Among the weather attributes, precipitation had the largest and most significant negative association with physical activity in both girls and boys. Of interest, among

girls I observed that compared to heavy precipitation, light precipitation had a larger negative effect on their daily step counts (-861 steps/day with light precipitation, compared to -728 steps/day with heavy precipitation, p-values<0.05). In boys however, the effect of light precipitation was smaller than that observed for heavy precipitation, and was not statistically significant. Heavy precipitation in boys was associated with 1107 fewer daily steps (p-value<0.05, Table 4.6).

Multivariable model

In the adjusted models, after controlling for weight status, school and non-school day, socioeconomic characteristics and school region, all of the weather attributes were related to activity levels in girls (p-values <0.05); conversely in boys, with the exception of heavy precipitation, none of the weather attributes were statistically significant in relationship to their physical activity. In girls, the estimates of the associations for daily average temperature and daily minimum temperature increased slightly after adjusting for other covariates. The average cloud coverage remained negatively associated with daily step counts in girls (-69 steps/day, p-value<0.05). Compared to no precipitation, light precipitation resulted in approximately 623 fewer steps taken per day and had a strong significant association (p-value <0.01). As the amount of precipitation increased to more than 5 mm, daily step counts declined more noticeably (-769 steps/day, p-value <0.01, Table 4.6).

Parsimonious model

In the parsimonious model, daily average feels-like temperature and total daily precipitation were significantly associated with physical activity in girls (+50 steps/day with every degree rise in feels-like temperature, -601 steps/day with light precipitation and -718 steps/day with heavy precipitation, p-values<0.05, Table 4.6). In boys, only heavy precipitation was negatively

associated with steps per day (β same as in multivariable model, p-value <0.02), independent of the effect of other covariates. The association between precipitation and step counts in boys did not differ significantly from that in girls.

In regard to other covariates of interest in this study, weight status was negatively related to step counts in both girls and boys. Compared to normal weight children, overweight girls and boys had on average 210 and 1069 fewer steps per day respectively (although not statistically significant), and obese girls and boys had 1264 (p-value<0.01) and 1362 (p-value<0.01) fewer steps per day respectively, independent of the effect of weather attributes and other covariates (Table 4.6). Children from households with highest income category had more steps taken per day compared to their peers from households with lower income categories (not statistically significant), and girls attending schools in Metropolitan areas were less active compared to girls in rural and urban schools (β= -1688, p-value<0.05).

4.6. Addressing Research Objective 6

Effect of Weather on Physical Activity Based on Different Activity Levels of Children

For this objective, children's activity levels were classified according to the cutoff recommended for meeting the current recommendations of 60 minutes of MVPA in children [6]. Children who accumulated more than or equal to 12,000 steps per day were considered as "meeting" the MVPA recommendations, and those with less than 12,000 steps per day were classified as "not meeting" the recommendations. The proportion of children meeting the guideline differed significantly between boys and girls and on school days compared to non-school days (Table 4.1). Stratified analysis was done to assess the difference in the association between weather and physical activity based on strata of activity levels. The results are presented in Table 4.7.

Analysis showed that among children who met the MVPA recommendations, the effect size for the outcome was generally more pronounced and significant, indicating that the effect of weather on physical activity was higher among children who were more physically active compared to children with lower activity levels. Among the more active children, the higher the temperature attributes, higher was the activity, with the effect size ranging between 24-43 steps/day with every unit increase in the ambient temperature (p-values<0.05). The associations were statistically significant after adjusting for other covariates. In contrast, among children who did not meet the MVPA recommendation, the effect of weather attributes was small. Interestingly, although daily minimum temperature was positively associated with step counts in more active children (+43 steps/day, p-value<0.05), its effect was reversed among less active children (-53 steps/day, p-value<0.05). However, the independent association was not statistically significant in less active children. Additionally, the relationship between daily maximum temperature and activity differed significantly based on strata of activity levels.

Children who were less active took 94 fewer steps per day as the average daily cloud coverage increased (p-value<0.01). The association remained significant in the parsimonious model (-34 steps/day, p-value<0.05). The negative effect of heavy precipitation on daily step counts was larger and stronger among more active children compared to less active children (-925 steps/day, p-value<0.05). In the parsimonious models, daily physical activity was positively associated with the daily maximum temperature in more active students (+35 steps/day, p-value<0.05) and negatively associated with daily average cloud coverage (-34 steps/day, p-value<0.05) in less active students. Other weather attributes did not have any significant relationship with physical activity when adjusted for other covariates.

Among other covariates of interest, student gender, weight status, and school/non-school day were significantly associated with physical activity in more active children, i.e. boys taking 1497 more steps/day compared to girls (p-value<0.05), overweight and obese children taking fewer steps per day compared to their peers with normal weight (β= -578 and -866 respectively, p-values<0.05), and more active children taking 1900 additional steps per day on school days compared to non-school days (p-value<0.05). Among less active children, with the exception of weight status and school/non-school day, none of the other covariates were associated with physical activity.

4.7. Tables and Figures

Table 4.1. Descriptive statistics and physical activity levels of grade 5 students sample in Alberta, Canada in 2013

	Girls **(n=562)**	Boys **(n=392)**	Total **(n=972)**[1]
Mean Age **(SD)**	10.8 (±0.4)	10.9 (±0.4) *	10.9 (±0.4)
Mean BMI[2] **(SD)**	19.4 (±4)	20.2 (±4.5) *	19.7 (±4.2)
Weight status[3], %			
Normal	58.8	50.2 *	54.2
Overweight (not obese)	21.7	20.0	20.6
Obese	19.5	30.0	25.2
Parent's education, **%**			
Secondary or less	25.2	28.3 *	26.4
College diploma	37.0	36.0	36.5
University or graduate	38.0	35.9	37.0
Household income, **%**			
≤ $ 50,000	22.8	20.8 *	22.0
$ 50,001- $75,000	13.8	12.5	13.3
$ 75,001- $ 100,000	16.0	14.3	15.2
≥ $100,001	47.5	52.3	49.5
School region, **%**			
Rural	12.0	10.0	12.0
Urban	53.0	52.0	53.0
Metropolitan	35.0	35.0	35.0
Physical activity, **Mean (SD)**			
Steps/day[4] in a typical week	10,413 (± 5135)	11,889 (± 6453) *	11,011 (± 5751)
Steps/day on school days	10,791 (±4443)	12,520 (±5581) *	11,483 (±5008)
Steps/day on non-school days	9,586 (±6315)	10,518 (±7860) *	9,953 (±6974)
Steps/hour	694 (± 851)	792 (± 997) *	734 (± 914)
Students with ≥12,000 steps/day[5] **(%)**			
School days	34.0	48.6 *	40.0
Non-school days	28.7	33.0 *	30.0

[1] Missing participant data for gender (n=18), for BMI (n=70), for parent's education (n=60), and for household income (n=389)

[2] kg/m^2

[3] Based on the WHO age and sex-specific BMI z-score cutoffs for children [3].

[4] Steps adjusted for non-wear time, non-ambulatory activities and missing data, based on MET units, during the time window between 7:00 am to 8:59 pm. A typical week was defined as 5 school days and 2 non-school days.

[5] Guideline for moderate to vigorous physical activity (MVPA) in children recommends ≥12,000 steps/day.

* Statistically significant difference between boys and girls based on p-value<0.05 of Student's t-test for continuous variables and chi-square test for categorical variables.

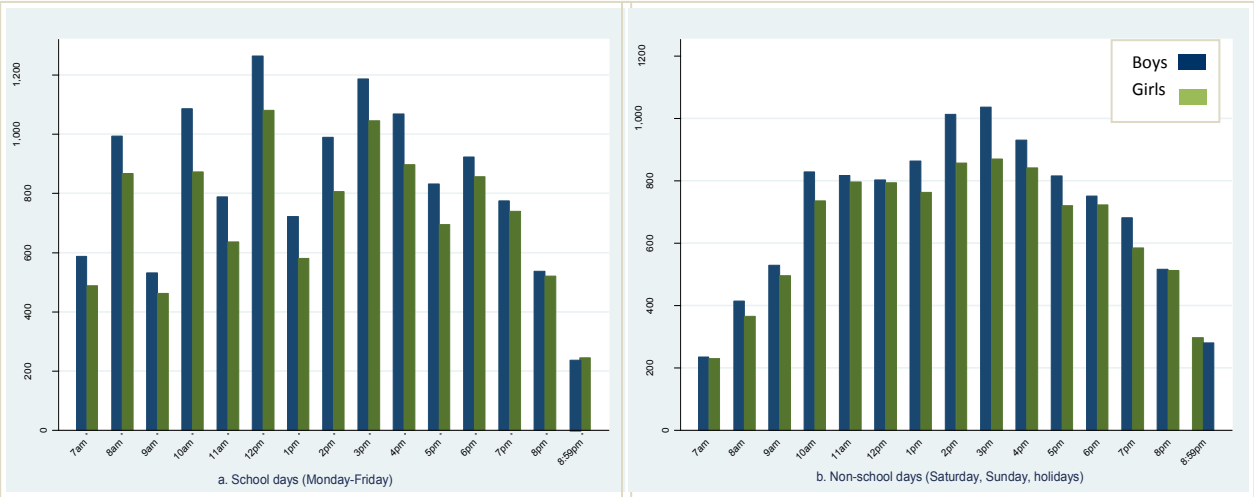

Figure 4.3. Mean number of steps per hour among 972 grade 5 students in Alberta, Canada on a) school days; and b) non-school days.

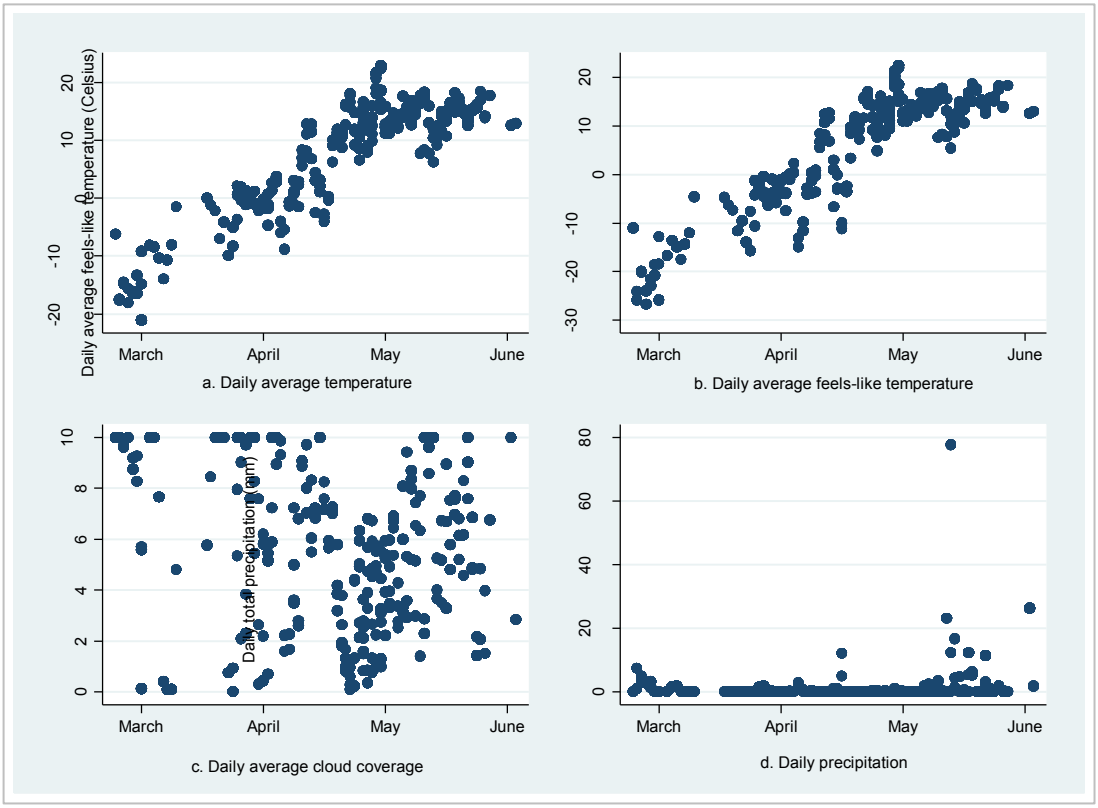

Figure 4.4. Variation in a) average daily actual temperature; b) average daily feels-like temperature; c) average daily cloud coverage; and d) total daily precipitation from 7:00 am to 8:59 pm between March to June, 2013 based on weather data for 23 regions across Alberta, Canada

Table 4.2. Weather attributes by month[1] in 23 regions across Alberta, Canada included in the study

	March	April	May	June
Daily average temperature, ^{o}C (SD)				
Actual	-12 (± 5.7)	1.0 (± 5.3)	12 (± 6.5)	14.6 (± 3.6)*
Feels-like	-17.0 (± 6.0)	-1.0 (± 6.8)	12.0 (± 6.5)	15.0 (± 4.0)*
Month minimum	-28	-14	-5	7
Month maximum	7	20	30	24
Daily average Cloud coverage [2] (SD)	6.4 (± 4.3)	6.2 (± 4)	4.6 (± 3.3)	5.0 (± 3.6)*
Proportion (%) of days with precipitation[3] measuring-				
None (0 mm/day)	64.2	75.4	78.0	54.3*
Light (0.01-5mm/day)	33.6	23.7	9.3	27.0
Heavy (>5 mm/day)	2.2	1.0	12.7	19.0

[1] Total of 5958 days of observation were analyzed, with 1080 days in March, 2370 days in April, 1842 days in May, and 666 days in June (total school days=4089, total non-school days=1869)

[2] Cloud coverage scores range between 0-10 with 0 being a clear sky and 10 being overcast.

[3] Precipitation includes both snowfall and rainfall

* Statistically significant difference in weather attributes between months (p-value<0.05)

Table 4.3. Associations between weather attributes and physical activity in 972 grade 5 students in Alberta, Canada in 2013

	Steps per day [1]					
	Univariable Model		Multivariable Model[2]		Parsimonious Model [3]	
	β	95% CI	β	95% CI	β	95% CI
Temperature ºC						
Actual	15	-16, 44	22	-7, 51		
Feels-like	23	-1, 48	24	1, 48		
Daily maximum	26	-1, 52	12	-14, 38		
Daily minimum	-25	-52, 2	11	-15, 38		
Cloud coverage [4]	-97	-135, -58	-61	-99, -22	-45	-85, -5
Precipitation/day						
None (0 mm)		-		-		-
Light (0.01-5mm)	-556	-880, -232	-209	-535, 116	-134	-468, 199
Heavy (>5mm)	-957	-1500, -416	-1022	-1557, -487	-888	-1436, -339
Gender						
Girls		-		-		-
Boys	1525	1056, 1995			1627	1157, 2097
Weight status						
Normal		-		-		-
Overweight	-570	-1176, 35			-593	-1183, -2
Obese	-1072	-1642, -502			-1234	-1810, -658
Household income						
≤ $ 50,000		-		-		-
$ 50,001- $75,000	-81	-1166, 1005			-4	-1035, 1026
$ 75,001- $ 100,000	-19	-1062, 1025			-58	-1060, 943
≥ $100,001	284	-578, 1146			411	-413, 1235
Parent's education						
Secondary or less		-		-		-
College diploma	-202	-813, 408			-48	-653, 556
University/ graduate	242	-385, 870			245	-376, 866
Day of the week						
Non-school day		-		-		-
School day	1447	1190, 1704			1398	1132, 1663
School region						
Rural		-		-		-
Urban	-1264	-2806, 277			-1112	-2637, 412
Metropolitan	-1160	-2904, 583			-1021	-2938, 895

[1] All weather attributes were considered as daily averages, except precipitation which is total measurement/day.
[2] Estimates for each of the weather attributes are derived from separate models, each model was adjusted for gender, weight status, household income and education, day of the week, and school region. Weather attributes are not mutually adjusted.
[3] The parsimonious model considered all statistically significant weather attributes and all other covariates. Weather attributes were subjected to purposeful selection method.
[4] Cloud coverage reported as a continuous variable ranging between 0-10, with 0 being the least and 10 being the most amount of cloud coverage.

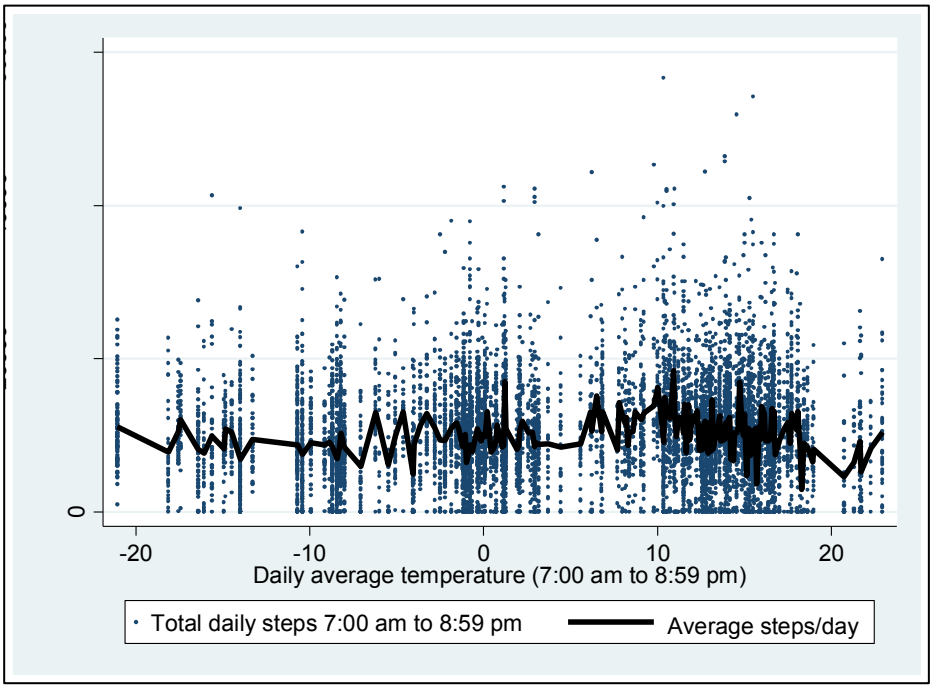

Figure 4.5. Relationship between average daily physical activity (steps/day) with average daily temperature

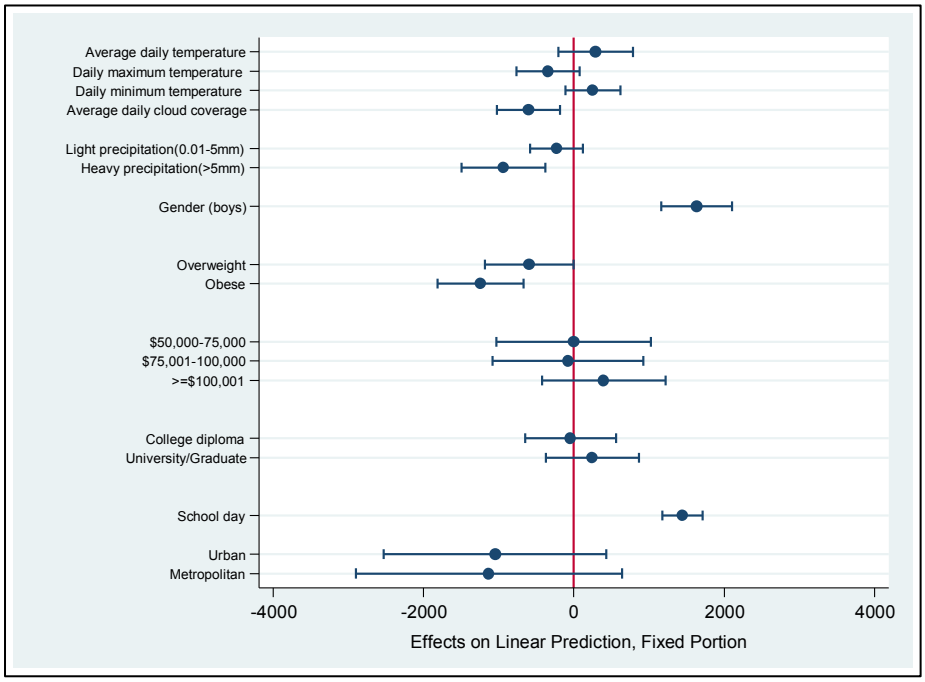

Figure 4.6. Average marginal effects with 95% confidence intervals for step counts per day with respect to 10^{o} C increase in temperatures (average daily, daily maximum and daily minimum), 10 unit change in cloud coverage, and light/heavy precipitation relative to no precipitation, adjusted for other covariates in the study.

Notes: The estimates are derived from the model with mutually adjusted weather attributes. Effect sizes are not exactly the same as the ones presented in table 4.3. Reference category for gender: girls, for weight status: normal weight, for household income: ≤ *$50,000, for parent's education: secondary/less, for day: non-school day, and for region: rural*

Table 4.4. Associations between weather attributes and physical activity on school days and non-school days for 972 grade 5 students in Alberta, Canada

	Steps per day on school days						Steps per day on non-school days					
	Univariable Model		Multivariable Model [1]		Parsimonious Model [2]		Univariable Model		Multivariable Model [1]		Parsimonious Model [2]	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Temperature ºC												
Actual	38	10, 67	35	5, 65			55	4, 106	65	16, 114		
Feels-like	38	14, 62	38	14, 63	33	8, 58	52	10, 95	60	20, 101		
Daily maximum	33	6, 60	28	-1, 55			48	-2, 99	56	8, 105		
Daily minimum	4	-22, 30	6	-20, 33			116	50, 82	130	70, 190	153	95, 212
Cloud coverage [3]	-17	-55, 21	-12	-50, 25			-177	-275, -80	-170	-267, -73	-221	-317, -125
Precipitation/day												
None (0 mm)		-				-		-		-		-
Light (0.01-5mm)	-485	-856, -114	-423	-793, -53	-402	-773, -31	-238	-415, 891	-232	-422, 886		
Heavy (>5mm)	-730	-1246, -214	-663	-1177, -148	-613	-1128, -97	-2346	-3820, -872	-2427	-3884, -969		
Gender												
Girls		-		-		-		-		-		-
Boys	1742	1292, 2193			1829	1378, 2280	1188	410, 1966			1320	545, 2095
Weight status												
Normal		-		-		-		-		-		-
Overweight	-371	-956, 215			-401	-967, 165	-936	-1868, -4			-991	-1940, -42
Obese	-1085	-1635, -535			-1277	-1828, -726	-1150	-2135, -164			-1174	-2147, -200
Household income												
≤ $50,000		-		-		-		-		-		-
$50,001-$75,000	-83	-1109, 943			-13	-1001, 974	90	-1720, 1900			141.02	-1552, 1834
$75,001-$100,000	-377	-1363, 609			-397	-1358, 562	845	-892, 2582			503.4	-1148, 2154
≥$100,001	8	-809, 826			108	-680, 897	1293	-125, 2711			1455	115, 2796
Parent's education												
Secondary or less		-		-		-		-		-		-
College diploma	-441	-1033, 152			-248	-828, 333	229	-767, 1225			369	-625, 1364
University/graduate	140	-470, 750			202	-394, 798	452	-566, 1472			402	-609, 1414
School region												
Rural		-		-		-		-		-		-
Urban	-632	-2193, 928			-302	-1769, 1163	-2888	-5139, -637			-1537	-3437, 363
Metropolitan	-677	-2629, 1274			-425	-2136, 1287	-2887	-5245, -530			-2301	-4258, -344

Table footnotes on the next page

Table 4.4 footnotes: Time window between 7:00am to 8:59pm was used in the analysis. Total number of school days=4089 (69% of observations), total number of non-school days=1869 (31% of observations). Non-school days included Saturday, Sunday, and holidays.

[1] Estimates for each of the weather attributes are derived from separate models, each model was adjusted for gender, weight status, household income and education, and school region. Weather attributes are not mutually adjusted.
[2] The parsimonious model considered all weather attributes and all other covariates. Weather attributes were subjected to purposeful selection method
[3] Cloud coverage reported as a continuous variable ranging between 0-10, with 0 being the least and 10 being the most amount of cloud

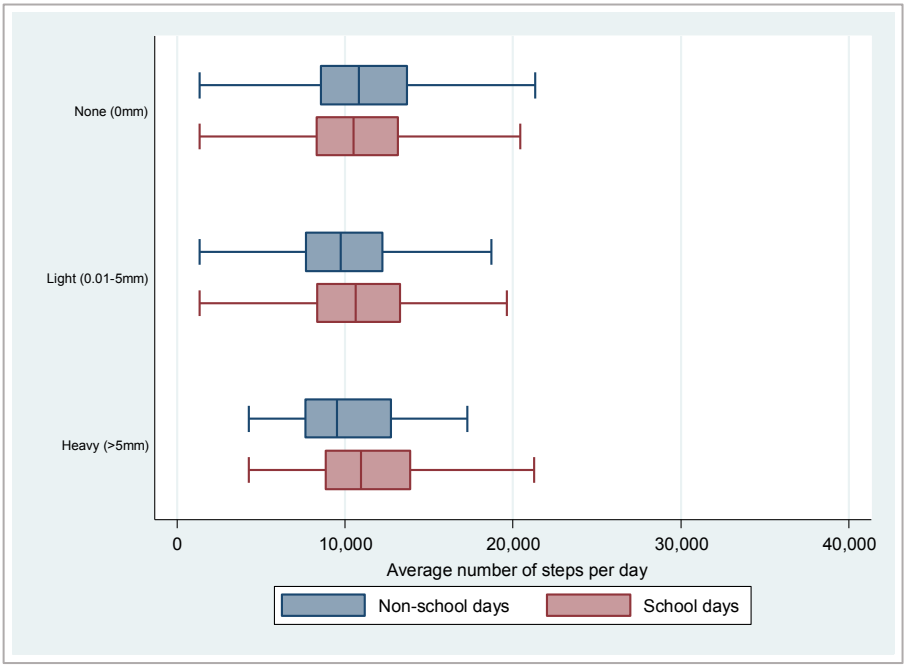

Figure 4.7. Relationship between average daily physical activity with the amount of precipitation occurring per day in 972 grade 5 students in Alberta, Canada on school days and non-school days

Table 4.5. Associations between weather attributes and physical activity (steps/hour) on school days by time of the day[1] in 972 grade 5 students in Alberta, Canada in 2013

	Before school						During school						After school					
	Univariable Model		Multivariable Model [2]		Parsimonious Model[3]		Univariable Model		Multivariable Model [2]		Parsimonious Model[3]		Univariable Model		Multivariable Model [2]		Parsimonious Model[3]	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95%CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Temperature °C																		
Actual	-1	-4, 2	-1	-4, 2			3	1, 5	2	1, 4			-14	-16, -11	-13	-16, -11		
Feels-like	-2	-4, 1	-1	-3, 1			3	2, 5	3	2, 5	4	2, 5	-8	-11, -7	-8	-10, -6	15	8, 21
Daily maximum	2	-1, 4	2	-1, 4	5	2, 9	1	-1, 3	1	-1, 3			2	-1, 4	2	1, 4	9	6, 12
Daily minimum	-7	-9, -4	-7	-9, -4	-8	-11, -4	-1	-3, 1	-1	-3, 1			1	-2, 3	1	-1, 3	5	2, 7
Cloud coverage [4]	-1	-4, 3	-1	-5, 2			-2	-4, 1	-2	-4, 1			-2	-5, 1	-2	-5, 1	-4	-8, -2
Precipitation/day																		
None (0 mm)																		
Light (0.01-5mm)	-92	-126, -58	-93	-127, -58	-58	-96, -21	-26	-48, -4	-26	-48, -4	-43	-63, -22	-32	-58, -6	-33	-59, -6	-61	-92, -31
Heavy (>5mm)	-27	-85, 30	-27	-84, 30	-2	-61, 56	-59	-96, -22	-58	-95, -21	-65	-102,-28	-84	-127, -39	-83	-126, -38	-142	-193, -92
Gender																		
Girls																		
Boys	82	44, 120			90	52, 127	134	101, 166			147	114, 179	71	24, 118			74	26, 122
Weight status																		
Normal																		
Overweight	-35	-83, 13			-38	-86, 10	-19	-62, 23			-28	-69, 13	-62	-121, -2			-63	-123, -2
Obese	-79	-124, -34			-87	-133, -40	-70	-109, -29			-92	-133,-52	-73	-128,-17			-78	-136, -19
Household income																		
≤ $ 50,000																		
$ 50,001- $75,000	-31	-115, 53			-26	-109, 57	13	-61, 87			19	-53, 91	-12	-116, 91			-18	-124, 87
$ 75,001-$ 100,000	-30	-112, 51			-33	-113, 48	38	-34, 109			28	-41, 99	-17	-117, 83			-26	-129, 76
≥ $100,001	-43	-109, 24			-50	-117, 16	45	-14, 104			22	-35, 80	63	-19, 145			48	-36, 133
Parent's education																		
Secondary or less																		
College diploma	10	-72, 26			-12	-61, 37	-17	-59, 26			-8	-51, 33	-2	-63, 58			3	-59, 64
University/graduate	-23	-40, 60			14	-36, 64	24	-20, 68			20	-23, 64	10	-51, 72			12	-52, 75
School region																		
Rural																		
Urban	6	-97, 107			15	-96, 127	-94	-208, 19			-64	-176, 47	-135	-260, -9			-210	-376, -43
Metropolitan	61	-46, 168			88	-27, 203	-51	-169, 67			-29	-145, 87	-162	-293, -30			-192	-365, -19

Table footnotes on the next page

Table 4.5 footnotes:

[1] On a typical school day, time windows between 7:00am-7:59am, 8:00am-3:59pm, and 4:00pm-8:59pm were considered as before, during and after school hours respectively

[2] Estimates for each of the weather attributes are derived from separate models, each model was adjusted for gender, weight status, household income and education, and school region. Weather attributes are not mutually adjusted.

[3] The parsimonious model considered all statistically significant weather attributes and all other covariates. Weather attributes were subjected to purposeful selection method

Table 4.6. Associations between weather attributes and physical activity (steps/day) by gender among 972 grade 5 students in Alberta, Canada [1]

	Girls (n=562)						**Boys** (n=392)					
	Univariable Model		**Multivariable Model** [2]		**Parsimonious Model** [3]		**Univariable Model**		**Multivariable Model** [2]		**Parsimonious Model** [3]	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Temperature ºC												
Actual	46	15, 77	54	25, 82			18	-26, 63	11	-36, 57		
Feels-like	46	21, 72	50	26, 73	50	27, 73	21	-16, 58	13	-25, 52		
Daily maximum	58	30, 86	56	29, 82			11	-30, 52	13	-36, 65		
Daily minimum	6	-24, 37	34	6, 63			-23	-67, 21	15	-28, 59		
Cloud coverage [3]	-99	-145, -53	-69	-115, -22			-89	-157, -22	-45	-112, 22		
Precipitation/day												
None (0 mm)		-		-		-		-		-		-
Light (0.01-5mm)	-861	-1251, -471	-623	-1015, -231	-601	-992, -210	-175	-738, 387	327	-241, 896	328	-241, 899
Heavy (>5mm)	-728	-1376, -80	-769	-1410, -128	-718	-1356, -80	-1107	-2080, -133	-1194	-2154, -234	-1194	-2154, -234
Weight status												
Normal		-		-		-		-		-		-
Overweight	-182	-835, 471			-210	-856, 436	-1200	-2314, -81			-1069	-2179, 41
Obese	-1347	-2030, -666			-1264	-1939, -588	-1471	-2465, -478			-1362	-2360, -365
Household income												
≤ $50,000		-		-		-		-		-		-
$50,001-$75,000	-513	-1734, 108			-496	-1625, 634	495	-1447, 2437			566	-1355, 2487
$75,001-$100,000	614	-573, 1800			-86	-1202, 1029	-969	-2802, 863			-507	-2343, 1330
≥$100,001	631	-378, 1642			67	-837, 971	-75	-1541, 1392			575	-921, 2073
Parent's education												
Secondary or less		-		-		-		-		-		-
College diploma	602	-81, 1286			657	-25, 1340	-991	-2074, 92			-691	-1782, 398
University/graduate	661	-31, 1354			520	-172, 1212	-231	-1346, 882			-23	-1137, 1091
Day of the week												
Non-school day	-		-			-	-		-		-	
School day	1216	902, 1530			1156	838, 1474	1777	1329, 2226			1859	1399, 2318
School region												
Rural		-		-		-		-		-		-
Urban	-1256	-2726, 213			-1112	-2296, 72	-1510	-3744, 723			-1315	-3545, 914
Metropolitan	-1667	-3588, 253			-1688	-2921, -454	-887	-3223, 1450			-483	-2811, 1844

Table footnotes on the next page

Table 4.6 footnotes:

[1] Missing gender (n=18). Missing observations were treated as a separate category in the regression models, the results are not presented in the table

[2] Estimates for each of the weather attributes are derived from separate models, each model was adjusted for weight status, household income and education, day of the week, and school region. Weather attributes are not mutually adjusted.

[3] The parsimonious model considered all weather attributes and all other covariates. Weather attributes were subjected to purposeful selection method

Table 4.7. Associations between weather attributes and physical activity (steps/day) in 972 grade 5 students in Alberta, Canada based on their compliance with moderate to vigorous physical activity recommendation[1]

	MVPA recommendation met						MVPA recommendation not met					
	Univariable Model		Multivariable Model [2]		Parsimonious Model [3]		Univariable Model		Multivariable Model [2]		Parsimonious Model [3]	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Temperature ºC												
Actual	33	4, 61	34	4, 63			-2	-18, 4	-1	-15, 14		
Feels-like	24	3, 45	27	4, 52			3	-10, 16	2	-10, 14		
Daily maximum	27	3, 50	34	7, 62	35	7, 62	7	-7, 22	-8	-22, 6		
Daily minimum	43	15, 72	31	1, 60			-53	-71, -34	-6	-21, 9		
Cloud coverage 3	-4	-63, 55	-33	-91, 25			-94	-120, -68	-35	-59, -9	-34	-59, -9
Precipitation/day												
None (0 mm)	-		-		-		-		-		-	
Light (0.01-5mm)	167	-336, 670	-211	-712, 288			-567	-791, -343	-71	-283, 141		
Heavy (>5mm)	-1171	-1970, -374	-925	-1708, -143			-247	-629, 135	-249	-604, 106		
Gender												
Girls	-		-		-		-		-		-	
Boys	1341	880, 1803			1497	1044, 1950	-76	-311, 160			57	-179, 295
Weight status												
Normal	-		-		-		-		-		-	
Overweight	-532	-1111, 46			-578	-1154, -2	-88	-380, 203			-72	-365, 221
Obese	-931	-1533, -330			-866	-1440, -292	-416	-687, -146			-426	-708, -145
Household income												
≤ $50,000	-		-		-		-		-		-	
$50,001-$75,000	-701	-1756, 353			-795	-1767, 177	79	-435, 593			73	-440, 587
$75,001-$100,000	-561	-1522, 488			-472	-1422, 477	200	-291, 691			122	-376, 620
≥$100,001	-16	-795, 762			27	-752, 807	65	-336, 467			27	-380, 434
Parent's education												
Secondary or less	-		-		-		-		-		-	
College diploma	-578	-1185, 29			-444	-1034, 145	8	-286, 302			-25	-326, 274
University/ graduate	-2	-615, 610			116	-476, 709	158	-141, 460			-109	-198, 316
Day of the week												
Non-school day	-		-		-		-		-		-	
School day	-1854	-2273, -1434			1900	2315, 1484	1976	1805, 2147			1930	1755, 2105

Table continued on the next page.

School region										
Rural	-		-	-		-		-		
Urban	-932	-1896, 31		-424	-1593, 743	-356	-1022, 309		-315	-946, 316
Metropolitan	-794	-1809, 220		-423	-2286, 1440	-190	-886, 505		-203	-869, 462

[1] Compliance with current recommendation for daily MVPA was defined as "not meeting" the recommendation if step counts was <12,000/day, and "meeting" the recommendation if step counts was ≥12,000/day. In total, MVPA was met by 37% and not met by 63% of observations.

[2] Estimates for each of the weather attributes are derived from separate models, each model was adjusted for weight status, household income and education, day of the week, and school region. Weather attributes are not mutually adjusted.

[3] The parsimonious model considered all weather attributes and all other covariates. Weather attributes were subjected to purposeful selection method

Chapter V

Discussion

5.1 Review of Key Findings in the Context of the Existing Literature

As evident from the literature, the environment can influence lifestyle behaviors in human populations [8-11]. School-aged children are in a dynamic state of growth, and as a result are adapting their lifestyle behaviors, therefore, examining factors that affect their physical activity habits will facilitate promoting a healthy childhood development. Although the weather is a factor that cannot be changed, modified or controlled, understanding and characterizing the weather attributes that act as barriers to physical activity in children is important to inform, plan, and deliver effective strategies for promoting physical activity in children. With this in mind, the main objectives of this thesis were to investigate daily physical activity levels of school-aged children in Alberta, its association with weather attributes, and to assess the effect modification of other variables on the relationship between the weather and physical activity. This study revealed a number of salient issues pertaining to differences in physical activity levels in children and its relation with weather attributes. In accordance with the research objectives being investigated, the key findings emerging from this study were that physical activity was significantly higher on school days compared to non-school days (i.e. Saturday, Sunday, and other holidays); boys were more active than girls regardless of day of the week; precipitation and cloud coverage had the most marked effect on daily levels of physical activity; and the effect of weather on physical activity varied by day type, time windows on a school day, gender of the children, and their compliance with the current recommendations for MVPA.

The average daily physical activity in this sample was approximately 11,000 steps per day in a typical week of five school days and two non-school days (11,889 in boys, 10,413 in girls). These estimates are very similar to the national (12,100 steps/day in boys, and 10,300 steps/day in girls) and provincial (an average of 11,100 steps/day) reported averages [12, 13]. In Canada, physical activity guideline recommends children aged 5-17 years should accumulate at least 60 minutes of MVPA per day in order to achieve associated health benefits [14]. To this date, different cut-offs have been suggested to establish an objective measure for 60 minutes of MVPA. While some studies suggest daily step counts between 15,000 to 16,000 is equivalent to 60 minutes of MVPA [15-17], others suggest lower cut-offs [18-20]. In this study, adherence to MVPA recommendation was considered as daily step counts of 12,000 or more, as this cut-off provides a more accurate estimate of meeting the recommended MVPA [6]. Based on this cut-off, children in this study showed a satisfactory adherence to the physical activity guidelines. It should be noted that the schools included in this study were under the APPLE Schools and HSHF programs, which aimed to improve healthy living in children through empowering the school community (explained in chapter III). Additionally, at the time of this study, a provincial Healthy Weight Initiative was in place at schools in Alberta to promote physical activity in children [21]. For these reasons, children in this study might have been aware of the importance of physical activity and consequently more active compared to children from other schools not receiving any interventions.

In the present thesis, physical activity was found to be significantly higher on school days than non-school days, and the difference in physical activity between boys compared to girls was more obvious on school days compared to the non-school days. This day to day variation in objectively measured physical activity is supported by the literature [19, 22-24]. In line with our finding,

several other studies have reported higher physical activity on school days [25-28]. This difference in activity levels between school days and weekend days could be the result of school policies and programs that are in place such as physical education classes provided by the schools and a requirement for a minimum of 30 minutes of Daily Physical Activity (DPA) for all students in grades 1 to 9 implemented by Alberta Education and mandatory recess periods during school time [29]. I found that boys were more active than girls on both school and non-school days, and the difference between boys and girls activity levels was more evident on school days. Data also revealed that proportion of students achieving the target step counts for meeting the recommended 60 minutes of MVPA [6] was higher on school days compared to non-school days (40% and 30% respectively), and more boys achieved the target step counts regardless of the day of the week. In support of these findings, several studies have also reported of gender differences in physical activity levels [20, 30-32]. The nationally representative data also shows that in Alberta gender differences are specifically significant for 11- 14 year age group, whereas in other provinces this difference is observed across all ages [33].

In the present study, I observed that socio-economic proxy indicators such as parental education attainment, household income, and school region (rural, urban, and metropolitan) can be associated with physical activity levels in children. This finding is contrary to the provincial report from Alberta indicating lack of significant relationship between socio-economic indicators at the family level and children's physical activity, however, at national level children from higher income households are reportedly more active [13].

In regard to weather attributes, results from this thesis showed that certain weather attributes can have a significant impact on daily physical activity in children and result in varying levels of daily steps accumulated. In the overall analysis (unratified), actual and feels-like temperature, and daily maximum and daily minimum temperatures had a positive influence on daily step counts, although the associations were not consistently significant statistically. When analysis was stratified based on different time windows on a school day, ambient temperature was found to have a negative relation with the physical activity before and after school hours, and a positive relation during school hours. The effect of the daily maximum and minimum temperatures were more variable during different time windows on a day; although both attributes were positively associated with physical activity after school hours, the daily minimum temperature had an inverse relation to physical activity before and during school hours. It should be noted that the daily maximum and minimum temperatures are generally reported as single record per day, therefore, although they may not reflect change in hourly physical activity accurately, but the associations are worth noticing. On the other hand, precipitation and cloud coverage were negatively associated with physical activity with a greater consistency across various analyses. Heavy precipitation (>5mm per day) and increased daily average cloud coverage were approximately associated with 1000 and 61 fewer step counts per day respectively, and precipitation had the most marked negative effect on daily physical activity. The associations observed in this data are consistent with previous research reporting the positive effect of increasing temperature and the negative effect of precipitation [34-41]. However, physical activity was not objectively assessed in all of these studies, and only two of them have used pedometer records [35, 39]. Among those with an objective measure of physical activity, timing and duration of data collection varied across the studies. Although most of these studies have found that precipitation/humidity affects physical

activity negatively, unlike the present study, they reported that temperature had a greater effect on physical activity compared to precipitation. This inconsistency in the results is possibly due to the diverse weather conditions across the study sites or different time frames of data collection in a year. Though, it is of importance to note that the total daily precipitation measurement in this study referred to the water equivalent to all types of precipitation, such as rain, snow, drizzle, freezing rain, etc. I did not have the data separated for snowfall and rainfall. Therefore, in all analyses precipitation represents both snow and rain, depending on the month of data collection. Typically, according to the Canadian Climate Normals, in the time frame used in this study the month of March has the least amount of precipitation measurement and most of it is in the form of snow. The month of June is the most pouring month with heavy rainfalls. For example, in Edmonton during 1981-2010, in March the average precipitation was 16.5 mm and snow depth was high as 15 cm. The monthly average precipitation in April was 28.7 mm which included 14.4 cm of snowfall, in May it was 49.4 mm including 6.5 cm of snowfall, and in June it was 72.7 mm, all of which was in the form of rain [42].

The time frame used in our study is conventionally considered as late Winter till late Spring in Canada. For this time of the year, as our data indicated, temperature generally follows an increasing trend [42]. Unlike temperature, precipitation and cloud coverage showed fluctuation over this period and did not follow a particular trend. Heavy precipitation was mostly observed in the months of May and June. This could be possibly a reason for finding greater associations with precipitation and not with temperature in our data because generally, people anticipate this seasonal variation in temperature and activities are planned accordingly. During winter months when it is perceived that temperature is not suitable for walking and outdoor activities, other indoor

activities are usually planned to counteract the decline in children's physical activity particular of that season or time of the year. In contrast, precipitation happens more randomly particularly during spring, and this uncertainty around precipitation is more likely to affect physical activity. Nevertheless, inclusion of temperature as a determinant should be considered when monitoring children's physical activity levels.

In addressing the study's second research objective, I found that differences in physical activity by day of the week (school day vs. non-school day) remained significant independent of the effect of weather attributes. This suggests that day type might have effect modification on the relationship between weather and physical activity in children; therefore analysis was stratified by school day and non-school day. When the results were stratified by day type, the association between temperature and physical activity became more pronounced. The effect of cloud coverage and precipitation was however more prominent in the un-stratified analysis. This distortion in the effect of the estimates could be due to the fact that in school-going children, the day of the week might be an independent determinant of their daily activity levels [43, 44]. Consequently, in the un-stratified analysis based on all days, the effect of temperature was less due to the additional effect or potential confounding effect of school vs. non-school days that was adjusted for in the analysis.

I found that the association between weather and physical activity was more evident on non-school days compared to school days. This finding is contradictory to the previous research in Canadian children showing a greater association between weather and activity levels on school days [34]. In their study, Lewis et al. reported that weather variables had more influence on children's MVPA and sedentary time on school days rather than the weekend days in the Canadian and Australian

sample that they studied; whereas, the study by Duncan et al. had similar findings to the present thesis. Their findings suggested a greater effect of mean ambient temperature on boys activity levels on weekends compared to school days [35]. Possibly the impact of the weather on physical activity is a complex issue that depends on multiple demographic variables. The reason for my findings could be that spontaneous and un-planned activities that generally take place on weekends and non-school days are more likely to be affected by unexpected variations in the weather. Additionally, schools provide an environment to engage children in regular physical activity programs, both indoor and outdoor. Therefore variation in weather attributes and unexpected changes in temperature are less likely to impact activity levels on school days due to other available indoor opportunities, for example during extreme weather conditions including sub-zero temperature and heavy rainfalls, children are kept indoors during recess periods. The present study indicated that the main weather attributes affecting physical activity on non-school days were daily minimum temperature and cloud coverage, whereas on school days feels-like temperature and precipitation were most strongly associated with physical activity (positively and negatively respectively).

Results from the stratified analysis further revealed that the magnitude of the effect of weather attributes on physical activity varied by time windows on a school day, gender of the students and by their activity levels. During a typical week, children spend most of their time either at school or commuting to and/or from schools which is, in turn, an important contributor to their daily activity levels [45]. By looking at hourly-based physical activity and weather data at different time windows on a day, I aimed to assess if weather potentially affects the mode of transport on school days. As the data suggested, in this sample, the difference in activity levels between weekday and

weekends was more obvious during time periods between 7:00 to 8:00 am, 2:00 to 4:00 pm and at 12:00 pm (Figure 4.3). The morning and afternoon time windows plausibly correspond to the time that children are commuting to and from school [25]. I found that when the weather attributes were not mutually adjusted (in multivariable models), the temperature had a negative association with hourly step counts before and after school hours, and positive association during school hours (approximately corresponding to the time windows mentioned above). This can be explained logically as in Canada during colder months when the temperature is lower people generally tend to use the public transport more often and hesitate using private vehicles due to icy road conditions [46]. Therefore, daily step counts might increase slightly with colder temperature as a result of active transport. On the other hand, the temperature seemed to positively influence physical activity during school hours. This is anticipated, as schools included in this study were part of the on-going healthy eating and active living interventions promoting physical activity [21, 47]. Apart from that, schools in Alberta have planned recess periods during the day and depending on weather conditions some activities take place outdoors [48]. As a result when temperature increases, outdoor activities and recess periods can positively influence step counts in children. This is supported by evidence suggesting that being outdoor is an important contributor to children's physical activity levels and children are more active when they are outdoor [49, 50].

When the weather attributes were mutually adjusted in the analysis (the parsimonious models), temperature was positively related to physical activity during all three time periods. Cloud coverage and precipitation, on the other hand, had a negative impact on activity, most noticeably after school hours (3:59-9:00 pm). This is the time when families and children usually have more

choices to plan their indoor or outdoor activities; therefore, it is reasonable to observe a more pronounced associations during this time window.

Another finding from this study that warrants attention was that children in urban and metropolitan regions had fewer steps taken per hour compared to children from rural regions, most significantly outside school hours. In support of this finding, previous research shows that built environments can influence children's daily activity in relationship to weather attributes [39, 51, 52]. Loucaides et al. reported that children in rural regions were more active in summer, while those in urban regions showed higher activity in winter [39]. Additionally, Katapally et al. reported that children living in regions with a higher diversity of destinations were more likely to accumulate higher step counts in relationship to the weather attributes [51]. Similarly, Tremblay et al. showed that activity in rural children was higher during summer, while urban children were more active during fall [52]. These findings imply that when designing interventions to promote physical activity, weather variability and geographical location need to be taken into account for effectiveness and positive improvement in physical activity. It should be noted that our estimates for time windows analysis was based on hourly step counts which although seems to be trivial, but when translated to a day, the effects are quite noticeable.

Results from this thesis further showed that the associations between physical activity and weather attributes was stronger among girls compared to boys. In girls, all of the weather attributes were significantly associated with daily step counts independent of the effect of school/non-school day and socioeconomic factors, whereas in boys only cloud coverage and precipitation were associated, with a much smaller effect compared to what was observed in girls. Although this

gender-related variation in the association has been reported in the literature, the evidence is contradictory, with some studies reporting the presence of gender differences in the estimates [24, 34, 35, 53], and others reporting none [9, 37, 54]. Duncan et al. reported that the effect of 10^{o} C increase in temperature was associated with an additional 3400 steps/day in boys with statistical significance, compared to an additional 2300 steps per day in girls which was non-significant. Whereas, Lewis et al. reported that in their Australian sample of children, maximum temperature was negatively associated with MVPA only in girls, while in the Canadian sample maximum temperature was positively associated with MVPA in both girls and boys [34]. Additionally, Chan et al. have also reported of gender influencing the association between weather-related indices and physical activity in an adult population, they found that rainfall had a larger effect on daily physical activity in females [24]. In the present study, this difference in the magnitude of effects could be due to the design of the study including different proportion of girls and boys in the analysis. Another potential reason for this could be that boys are inherently more active than girls [55], which was also observed in our study. Boys also demonstrate greater self-efficacy in overcoming environmental barriers to physical activity such as participation in school sports, participation in community sports teams, and involvement in community physical activity organizations [56]; as a result, external factors such as weather attributes are less likely to impact their activity levels.

This study found that the effect of weather attributes on physical activity was larger and stronger among more active children, i.e. those who met the recommended target step counts for 60 minutes of MVPA. This finding is novel and adds to the literature, as to my knowledge none of the previous studies among children have assessed the impact of weather on physical activity based on how active the individuals are. In contrast to this finding, previously research in adult populations have

shown that weather could have a larger impact on daily activity levels of less active subgroups such as females and elderly [57-59]. My study indicated that, among children showing adherence to physical activity guideline recommendations, daily average temperature and daily maximum and minimum temperatures were positively and significantly associated with daily step counts and precipitation was negatively associated, while in less active children the only significant effect on their step counts was with cloud coverage (in reverse direction). This implies that children who are viewed as more active and engage more in physical activity, tend to increase their activity levels further with favorable weather conditions and are more influenced by their environment compared to less active children. It is also possible that children with lower activity levels, participate in fewer planned or un-planned activity programs on any day of the week, and therefore show less variation in their step counts with changes in weather attributes. Nevertheless, this observation is an interesting finding that warrants further investigation.

5.2 Study Strengths and Limitations

Strengths of the current study include an objective assessment of physical activity using time-stamped pedometers to ensure accurate physical activity measurement, and adjusting the step counts for non-ambulatory, non-wear time, and missing data based on daily activity logs completed by the students. This allowed considering for the activities that were not recorded by the pedometer. The imputation method used in this study that included using pedometer data from other randomly selected days within an individual and within the day of a week (school days and weekend days) to account for the non-ambulatory/non-wear time activities, ensured more accurate replacement of the missing data and is therefore more representative of the actual physical activity of children [25]. For considering a pedometer data to be complete, this study had a minimum of 8-

hours wear time criteria on at least three weekdays; as a result, the sample size was comparatively large ensuring more precise estimates. In order to eliminate potential measurement error due to differing administration time, data from the first and last day of the pedometer records was not included in the study [26]. The analyses for different time windows in a day (before, during and after school hours) was based on the hour-to-hour relationship of physical activity and weather data which is an important strength as it provides better and stronger evidence of the associations compared to day-based analysis. Other strengths of this study include obtaining accurate and reliable meteorological data for the province, use of individual repeated measures in the analysis that represent a better picture of physical activity of children in a typical week, and use of multilevel mixed-effect models to accounts for the clustering effect of individuals within schools and schools within regions across Alberta. This study was conducted under the supervision of Dr. Paul Veugelers, who is the principal investigator for the REAL Kids Alberta survey, and who has extensive research experience in epidemiology, nutrition and childhood obesity. His research knowledge and expertise has added strength to this study. Despite these strengths, there are few limitations in this study that need to be acknowledged.

A possible limitation of this research might arise from its cross-sectional design which provides only a snapshot of the study period and cannot ascertain a temporal relationship between factors studied. Although the original data source for this study is based on a population-based survey, the sample of students included in the current study is not representative of the provincial population, as the schools were not randomly selected. This fact limits the generalizability of our findings. Physical activity and weather data were available for a relatively limited time frame between March to June 2013, it is possible that the estimates of associations found in this study would be

larger or different over an extended period of observation. Also, with stratified analysis, varying sample sizes or number of observations in each stratum might result in variation in statistical power of the estimates. Another potential limitation of this study is that physical activity data for study participants was not collected at the same point in time. Data was collected over a week from all children within each school separately and not at the same time across all schools. It is, therefore, possible that localized weather conditions experienced by children at each school were not the same. However, exploratory analysis of the weather data suggested that the difference in weather attributes across the regions where the schools were located was negligible. Additionally, the purpose of this study was to assess within individual variation in physical activity in relation to the weather attributes, and the data was analyzed based on day-matched physical activity and weather data for each participant, therefore, the difference in the localized weather conditions should not limit the findings.

The present study considered the potential effect of day to day variation in weather attributes on physical activity, therefore unlike other studies that are similar to this research, I did not adjust for the month of data collection, as month was not a potential confounder in our data. Another limitation in the weather data was that precipitation reported referred to both snowfall and rainfall, although the effect of the two could be widely different on activity levels of children, we were not able to distinguish between the two.

Finally, it should be noted that despite necessary precautions and considerations taken into accounts, as with any other observational studies there is a possibility of residual confounding in

our study as a result of unrecognized potential confounders or measurement inaccuracies that should be acknowledged.

5.3 Public Health Implications

Findings from this study have important implications for planning, designing, and implementing future studies. Successful promotion of physical activity in children requires both individual-level and population-level interventions. The latter is of particular importance, as even a small shift in a population can result in major public health benefits [60]. Given that in Alberta as well as other provinces in Canada weather changes considerably not only across a year, but also from day to day within a single month or a season, it is important to put the current evidence into context and identify the most effective periods to intervene in order to increase activity levels in children and promote a healthy lifestyle.

Findings from this study further added to the existing evidence that certain aspects of weather can influence physical activity in children markedly. This knowledge should guide and encourage local governments to boost infrastructure for diverse facilities that support a wide range of year-round activities involving children, such as ice-hockey, cross-country skiing, accessible and low-cost indoor sport facilities, multi-purpose program spaces, and community recreation sport facilities. Evidence suggests that in Canada, even in cities with prolonged cold climate, the number of outdoor recreational facilities is more than the indoor facilities [61]. This implies that there is a need to bring change in the provision of publicly accessible indoor facilities with a focus on the influence that weather can have [62]. Moreover, encouraging active transport in all weather conditions and creating a supportive built environment that promotes active transport such as

"winter-paths" or launching national walk-to-school days year round, increasing road safety in winter by cleaning snow/ice, allocating bike lanes, considering tax credits for active transport, etc should be the focus of public health interventions and local governments in order to mitigate the declined levels of activity that occur as a result of poor climates. Additionally, since after school hours, weekends and holidays can be an important time to intervene, therefore, focus should also be given to health education to promote self-efficacy for physical activity in children during these times.

Schools can have a very important role in overcoming the weather-related barriers to physical activity. Schools are recognized as a place where lifestyle habits are shaped in children as they spend most of their time at school, and therefore school environments could be an ideal setting for effective public health interventions [63, 64]. Developing weather-appropriate and indoor activity programs for wet and colder days and investing in an infrastructure that aims to increase children's physical activity in unfavorable conditions have the potential to prevent a decline in their activity levels. Besides, in school-going children, physical activity levels depend on the structure of the academic year and available opportunities at schools [65]. In Canada, schools typically have a longer summer closure and shorter winter holidays. Changing the structure of the academic year to shorten the summer holiday and instead increase the winter closure could be a future consideration in regions with a colder climate like Alberta. If sustained in a long term, this change might result in lesser decline in physical activity in children as a result of seasonal variation and they will benefit further from available outdoor activity programs that can be arranged by schools when weather is favorable.

Family environments and parents can also play a significant role in shaping healthy lifestyle behaviors in children [66, 67]. The present study indicated that weather can influence children's activity levels outside the school and on non-school days noticeably. This dictates that parents and families can also play an important role in minimizing the negative impact of weather on physical activities of their child, for example by arranging other cost-effective indoor activity choices or by promoting safe walking and use of appropriate clothing for outdoor activities.

Lastly, public health interventions and school policies need to focus on specific subgroups with lower physical activity levels, including girls and overweight and/or obese children as our data indicated these groups were less active, and therefore, are at a higher risk of negative consequences such as, overweight and obesity in later years and associated chronic health conditions [68-71]. Structured physical education classes and gender-focused interventions should be focused to ensure physical activity is promoted equally among both girls and boys [21, 72]. Given the significant proportion of overweight and obesity in Canadian children, it is important to plan school policies and public health interventions that target overweight/obese children in particular, not in an attempt to reduce their adiposity, but to promote positive lifestyle behaviors among them in order to decrease or at least slow down unhealthy weight gain. Moreover, promoting routine physical activity behaviors at a young age will have benefits beyond weight management and is associated with improved cognition and better academic performance [73-75].

5.4 Conclusions and Recommendation for Future Research

In summary, data from this study provided evidence that weather can influence physical activity in young children. This study demonstrated that children were less active on days with varying

amounts of precipitation, and cloudier skies. Ambient temperature had a modest, but a positive influence on the physical activity of children. The magnitude of the effect of weather attributes on activity levels varied according to the day of the week, different time periods on weekdays, the gender of the students, and how active they were. Physical activity was significantly higher in boys, and on school days and the difference between school and non-school days was more obvious at certain time windows.

The findings suggest that future studies and interventions involving physical activity in children and other populations should accounts for weather attributes as important covariates in design, analysis, interpretation and evaluation of their outcomes. Identifying significant and meaningful interactions between weather attributes and potential confounders could be another area for future research that requires further investigation. In this study, the most significant association of physical activity was found to be with precipitation. Data on precipitation was reported as total amount accumulated in a day, however, within-day variations in the amount of precipitation or prolonged sudden periods of heavy rainfall and snowfall can have a different effect on physical activity. This is something that could be considered, and within day variation of weather attributes and its effect on physical activity levels need to be further studied. Longitudinal studies with a standard framework for the collection of meteorological information and assessment of physical activity in relationship to weather would provide invaluable data that will ensure comparability across studies, establish a causal association, and will provide a more precise understanding of variations in physical activity levels that is influenced by weather. There is also a need to design studies with multiple observations over longer time frames, which allow capturing a full range of weather variation and changes in physical activity. Nevertheless, more observational studies in

this field are also useful to identify and quantify the exact environmental barriers to physical activity in order to guide and support interventions and policy developments.

5.5 References

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Appendices

Appendix A: Study Sites in Alberta

Table A: Study sites in Alberta and number of schools and students located at each site included in the study

Site name	Number of schools	Total number of students at each site
Athabasca	2	63
Beaverlodge	1	18
Bonnyville	1	36
Burdett	1	13
Cardston	1	26
Clairmont	1	27
Cremona	1	14
Duffield	1	19
Edmonton	21	393
Fort McMurray	14	390
High Prairie	1	31
Jenner	1	2
Lamont	1	30
Magrath	1	38
Manville	1	16
Morinville	1	11
Plamondon	1	9
Redcliff	1	40
Sherwood Park	3	72
Spruce View	1	13
Stony Plain	1	36
Vermilion	1	28
Wabasca	2	19
Total	**60**	**1344**

Appendix B: Sample Home Survey with Consent Form

Home Booklet 2013

This booklet has 3 parts:

1. Information about REAL Kids Alberta, 2. Consent Form, 3. Home Survey

Part 1 | Information about REAL Kids Alberta

Purpose: Your child is attending an APPLE School where healthy eating and active living are promoted. To help assess the benefits of the APPLE Schools program, we invite you to take part in this evaluation, Raising healthy Eating and Active Living (REAL) Kids Alberta. The School of Public Health at the University of Alberta, in partnership with the Government of Alberta, is conducting this evaluation. While taking part is voluntary, we encourage you and your Grade 5 child to participate by contributing valuable information that will help improve the health and learning of children in Alberta.

You and your Grade 5 child are being invited to participate.

Participation:

Your participation in this evaluation is voluntary. You can participate by completing part 3 of this booklet: the *Home Survey*, which will take about 15 minutes of your time. To give permission for your child to participate, we are asking you to complete and sign part 2 of this booklet: the *Consent Form*. We will only invite your child to take part with your consent. Her or his participation is also voluntary. We will not contact you or your grade five child in the future.

Consent:

We seek your consent to have your child participate in the survey at school. If you provide this consent, your Grade 5 child will be asked to do the following:

a. Complete a survey at school that asks questions about nutrition, physical activities, lifestyle and health.
b. Have her/his height, weight and arm span measured at school by a trained evaluation assistant. Students will be asked to remove their shoes before being measured. Measurements will be confidential and not shared with your child or any other school personnel. Your child's teacher and two evaluation assistants will be present at all times while the measurements are taken.

What we can learn from your participation:

This evaluation will help us answer questions such as:

- How aware are parents and students of healthy eating and active living initiatives supported by Alberta Health and Wellness?
- What do Alberta children know about the importance of healthy living?
- What are the eating habits and lifestyles of Grade 5 children in Alberta?
- How active are Grade 5 children in Alberta?
- How are eating habits and lifestyles affecting learning?
- Are healthy eating and physical activity preventing disease among children in Alberta?

How we will keep your personal information confidential:

We ask for your child's name so we know who has permission to participate in the project. We will also use this name to connect your responses to those of your Grade 5 child. We will keep all names confidential. Responses from you and your child will be kept confidential and will not be shared with anyone including your child's school. Individual schools and participants will not be identified when the findings are presented. We will treat the information with the highest level of respect and use it for evaluation purposes only. Completed surveys will be kept in a locked filing cabinet for 5 years following the completion of the project and then confidentially shredded. The Human Research Ethics Board of the University of Alberta, who makes sure that research is done with the highest ethical standards, has approved this project. The Research Ethics office can be reached at 780-492-0302.

Benefits of taking part:

- The findings from this project will provide valuable information to support Alberta Health and Wellness and Alberta Education initiatives that promote healthy eating, active living and positive learning outcomes for children and youth in Alberta.
- A summary of the findings will be posted on our website at www.realkidsalberta.ca.

Possible risks of taking part:

- You will share information about yourself and your Grade 5 child with us.
- Some people are uncomfortable with information on healthy eating, active living and health.
- Please be assured that your information and that of your child will only be used for evaluation purposes described above. Your information and that of your child will not be shared with other students, teachers, school staff or anyone else. The University of Alberta Health Research Ethics Board has approved the evaluation and your school's principal and school authority have also approved and given support for this evaluation.
- Your consent will be valid from the date signed, and may be withdrawn at any time by contacting the Project Coordinator, at 780-492-5472 or wendy.davis@ualberta.ca

Who is doing this evaluation?

Dr. Paul Veugelers at the School of Public Health, University of Alberta, is conducting this evaluation in collaboration with Alberta Health and Wellness and Alberta Education. His contact information is:

School of Public Health, University of Alberta

6-50 University Terrace Building, Edmonton, AB CANADA T6G 2T4

Tel: (780) 492-9095 Fax: (780) 492-5221

Email: Paul.Veugelers@ualberta.ca

Questions and Concerns:

Please see website for more information on the project: www.realkidsalberta.ca

For any questions about this project, please contact either Dr. Paul Veugelers at (780) 492-9095 or the Project Coordinator Wendy Davis at (780) 492-5472 or by e-mail at wendy.davis@ualberta.ca.

Part 2: Consent Form

CONSENT 1	☐ Yes
I have read the above information about REAL Kids Alberta.	☐ No
I understand that participation is voluntary.	
I give my consent for my Grade 5 child to take part in the student survey.	
My Grade 5 child's first and last names (please print below):	
_____	
Your name (please print below):	
_____	
Your signature (below):	
_____	
Date:	

PART 3 | Home Survey

Please take your time and choose the answer that best describes you and your grade five child. There are no right or wrong answers. If there is a question that you don't want to answer, you don't have to. Your response will be kept PRIVATE and completely ANONYMOUS.

……

Section 1: Where you live

1-1 What are the first 3 digits of your postal code? ___ ___ ___

1-1 If you live in a town or city, please indicate how much you agree with the following statements about where you live.
If you live in a rural setting, please consider both the place where you live and where you access services for your family, depending on which is more appropriate when responding to the following statements.

	Strongly disagree	Disagree	Agree	Strongly agree
I like where I live.	☐	☐	☐	☐
It is safe for children to play outside during the day.	☐	☐	☐	☐
In my neighbourhood / community there are good parks, playgrounds, and/or places to play.	☐	☐	☐	☐
In my neighbourhood / community there are sidewalks on most of the streets.	☐	☐	☐	☐
Traffic makes my neighbourhood / community an unsafe place for my child.	☐	☐	☐	☐
In my neighbourhood / community, there are good sports and recreational programs for my child.	☐	☐	☐	☐
In my neighbourhood / community, it is easy to purchase fresh fruits and vegetables.	☐	☐	☐	☐

Section 2: Your grade five child's activities and sleep

2-1 On a fair weather day, please indicate how your grade five child usually travels to and from school.

	School Bus	City Bus / City Train	Walks/Bikes	Is Driven	Others
To School	☐	☐	☐	☐	☐
From School	☐	☐	☐	☐	☐

2-2 Please indicate how long it usually takes your grade five child to get to and from school.

	15 minutes or less	16 to 30 minutes	31 to 45 minutes	46 to 60 minutes	More than 60 minutes
To School	☐	☐	☐	☐	☐
From School	☐	☐	☐	☐	☐

2-3 Think about the last 12 months. Please indicate how often your grade five child usually does the following activities **outside of school hours.**

How often does your child usually …	Never	Less than once a week	1-3 times a week	4 or more times a week
play sports or do physical activity **WITHOUT** a coach or instructor (such as riding a bike, skateboarding, rollerblading, etc.)?	☐	☐	☐	☐
play sports **WITH** a coach or instructor, other than in physical education (PE) (soccer, swimming lessons, hockey, gymnastics, etc.)?	☐	☐	☐	☐
engage in physical activities together with one or both parents/guardians like going for walks, jogging, bike riding, swimming, dancing or skating?	☐	☐	☐	☐

2-4 On average, about how many hours per day does your grade five child spend on the following activities, outside of school hours?

	Less than 1 hour a day	1-2 hours a day	3-4 hours a day	5 or more hours a day
Using a computer or playing video games	☐	☐	☐	☐
Watching TV	☐	☐	☐	☐
Using a cell phone, tablet, or iPad®				

2-5 Are any of the following technologies being used in your grade five child's bedroom?

	Yes	No	Sometimes
Television and/or DVD player	☐	☐	☐
Computer	☐	☐	☐
Tablet, iPad	☐	☐	☐
Video game console	☐	☐	☐
Cellular phone or other handheld communication device	☐	☐	☐

2-6 Please answer the following questions about what time your grade five child wakes up in the morning and gets into bed at night. Please fill in only one bubble per row.

At what time does your child usually *wake up* during:	**Before 6:30 am**	**6:30 – 7 am**	**7-7:30 am**	**7:30-8 am**	**8-8:30 am**	**8:30-9 am**	**After 9 am**
the week	☐	☐	☐	☐	☐	☐	☐
the weekend	☐	☐	☐	☐	☐	☐	☐

At what time does your child usually *get into bed* during:	**Before 8 pm**	**8-8:30 pm**	**8:30-9 pm**	**9-9:30 pm**	**9:30-10 pm**	**10-10:30 pm**	**After 10:30 pm**
the week	☐	☐	☐	☐	☐	☐	☐
the weekend	☐	☐	☐	☐	☐	☐	☐

2-7 How long does it usually take your child to fall asleep after getting into bed?

- ○ Less than 10 minutes
- ○ 10-15 minutes
- ○ 15-20 minutes
- ○ 20-25 minutes
- ○ more than 25 minutes

2-8 Thinking about the past 3 months, how often does your grade 5 child usually wake up at night after going to sleep?

- ○ Never or almost never
- ○ About once or twice per month
- ○ About one to three times a week

- Once per night on most nights
- Several times a night on most nights

2-9 Does your child snore?

- Never
- Occasionally
- Frequently
- Always

2-10 Does your child wake up feeling unrefreshed in the morning?

- Never
- Occasionally
- Frequently
- Always

2-11 Does your child have a problem with sleepiness during the day?

- Never
- Occasionally
- Frequently
- Always

Section 3: Your grade five child's health and behavior

3-1 What is your grade five child's date of birth?

Day: ____ ____ Month: ____ _____ Year: ____ ____ ____ ____

3-2 What is your grade five child's gender?

- Girl
- Boy

3-3 How many servings of vegetables and fruit should a grade 5 child eat each day?

_____ servings

3-4 How many minutes of moderate to vigorous physical activity should a grade 5 child be active for each day?

_____ minutes

3-4 To what extent do you encourage your grade five child to …

	Not at all	A little bit	Quite a lot	Very much
eat healthy foods?	☐	☐	☐	☐
help choose and prepare snacks and meals?	☐	☐	☐	☐
be physically active?	☐	☐	☐	☐
limit their time watching TV?	☐	☐	☐	☐
limit their time playing video games?	☐	☐	☐	☐
go to bed on time?	☐	☐	☐	☐

3-5 Does your grade five child make suggestions for your family to:

	Does not	A bit	Quite a lot	Very much
eat healthy?	☐	☐	☐	☐
be physically active?	☐	☐	☐	☐

3-6 How much do you …

	Not at all	A little bit	Quite a lot	Very much
personally care about staying fit and exercising?	☐	☐	☐	☐
personally care about eating healthy foods?	☐	☐	☐	☐

3-7 Please indicate whether the following applied to your household food situation in the last 12 months.

	Yes	No	Don't know
Did you ever eat less than you felt you should because there wasn't enough money to buy food?	☐	☐	☐
Were you ever hungry but didn't eat because there wasn't enough money to buy food?	☐	☐	☐

3-8 Please read the following statements and choose the answer that best describes your grade five child.

My grade five child…	Never or rarely	Sometimes	Regularly	Most of the time	Always	Unsure
does the right thing without being asked	☐	☐	☐	☐	☐	☐
sets goals and plans ahead	☐	☐	☐	☐	☐	☐
does her/his homework before play	☐	☐	☐	☐	☐	☐
tries to find alternative solutions when in conflict with others	☐	☐	☐	☐	☐	☐
listens when others are talking to her/him	☐	☐	☐	☐	☐	☐
works well in groups	☐	☐	☐	☐	☐	☐
takes care of her/his physical health by choosing healthy snacks, exercising, and getting enough sleep	☐	☐	☐	☐	☐	☐

Section 4: Alberta Health and Wellness Programs

4-1 How strongly do you agree with the following statements:

Schools with grade five students should:	Strongly disagree	Disagree	Agree	Strongly agree
Limit the availability of unhealthy foods such as chocolate, candy, French fries, potato chips, pop	☐	☐	☐	☐
Ban the serving of these unhealthy foods at school	☐	☐	☐	☐
Discourage students from bringing unhealthy foods to school	☐	☐	☐	☐
Not allow students to bring unhealthy foods to school	☐	☐	☐	☐

Follow the Alberta Nutrition Guidelines to guide their school in offering healthy food choices	□	□	□	□
Follow the Alberta provincial daily physical activity (DPA) guidelines by getting students physically active for 30 minutes each day	□	□	□	□

Alberta Health and Wellness has developed a number of Healthy Weights Initiatives. Examples include:

1. **Alberta Nutrition Guidelines for Children and Youth**
2. **Alberta Healthy School Community Wellness Fund**
3. **Healthy School Community Award**

The following three questions relate to these AHW Initiatives.

4-2 Are you aware of the Alberta Nutrition Guidelines for Children and Youth that provide information on foods that should and should not be provided within the school, daycare, and recreation environments?

- Yes
- Unsure
- No

4-3 Are you aware of the Alberta Healthy School Community Wellness Fund?

- Yes
- Unsure If no or unsure go to question 4-4
- No

If yes, have you done any of the following? (Fill in all that apply)

- Been involved in an application process
- Developed a formal partnership with community stakeholders in order to apply for the fund
- Received funding from the Wellness Fund
- Been motivated to improve physical activity and healthy eating in my child's school as a result of receiving Wellness Funds
- Applied but did not receive funding from the Wellness Fund
- Been motivated to improve physical activity and healthy eating in my child's school as a result of just applying for the Wellness Funds even though you did not receive funding
- Chosen not to apply for the fund

4-4 Are you aware of the Healthy School Communities Award?

- Yes
- Unsure If no or unsure go to question 4-5
- No

If yes, have you or a committee you are involved with done any of the following? (Fill in all that apply)

- Nominated someone or a school group for the award
- Received a nomination

- Been involved with an individual or group from your child's school community receiving an award
- Received an award
- Been motivated to make changes to healthy eating and physical activity in your child's school community as a result of receiving the award
- Received information but chosen not to participate in the award process at this time

4-5 Are you aware of the Canadian Physical Activity Guidelines, which describe the amount and types of physical activity recommended for good health?

- Yes
- Unsure
- No

4-6 Are you aware of the Canadian Sedentary Behaviour Guidelines, which are intended to help encourage Canadians to limit the time they spend watching TV, playing video and computer games, and to reduce other sedentary behaviours?

- Yes
- Unsure
- No

Section 5: Your household

5-1 Are you….

- Female
- Male

5-2 Were you born in Canada?

- Yes
- No

5-3 What is the highest level of education that you have attained?

- No schooling
- Elementary
- Secondary
- Community/Technical College
- University
- Graduate University

5-4 What is your current household income from all sources? (Optional)

- Less than $25,000
- $25,001 - $50,000
- $50,001 - $75,000
- $75,001 - $100,000
- More than $100,000
- Don't know / prefer not to answer

Please use this area to give us any further comments, suggestions or information

_____
_____
_____
_____
_____

Thank you for completing this survey! Your input is greatly appreciated.

Please check if you completed the consent form (part 2) if you would like your child to participate. Please put this booklet into the return envelope, seal the envelope, and give it to your fifth grade child to take to school. His or her teacher will collect the envelope.

Appendix C: Sample Student Survey

Student Survey 2013

REAL Kids Alberta Student Consent

This evaluation asks you questions about the foods you eat, the types of activities that you take part in and what you know about healthy eating and active living. We also will measure your arm span, height and weight in private. Your answers will help us learn more about the health of children in Alberta.

Your answers will be kept PRIVATE. They will not be shown to anyone from your school or your family. Your participation is voluntary.

I understand the information given to me about the survey and measurements.

I agree to take part in this evaluation.

☐ Yes ☐ No

Your printed name: ___________________________________

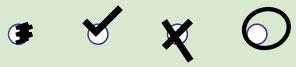
Today's date: ___________________________________

The evaluation assistants who are visiting your class will give instructions on how to answer the questions. Take your time and answer each question with the response that best describes your activities and the foods you eat. There are no right or wrong answers. If you need help or have any questions, please ask one of the assistants visiting your class. If there is a question that you don't want to answer, you don't have to.

Marking Instructions

- Use an HB pencil only
- Make dark marks that fill the bubble completely
- Erase clearly any mark you wish to change

Correct Mark **Incorrect Mark**



When you finish the survey, please put it in the envelope and the evaluation assistant will collect it.

Thank you for your help!

Section 1: The activities you take part in and the foods you eat.

1-1 Please fill in how much you agree or disagree with the following statements

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
I enjoy doing physical activity.	☐	☐	☐	☐	☐
I enjoy doing sedentary habits like watching TV or playing computer/video games.	☐	☐	☐	☐	☐

1-2 Do you have a chance to be physically active in other classes besides physical education?

- ○ No
- ○ Yes, some other classes
- ○ Yes, most other classes
- ○ Yes, all other classes
- ○ Don't know

1-3 In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Mark only one)

- ○ I don't participate in PE. Why? _____
- ○ Hardly ever

- Sometimes
- Quite often
- Always

1-4 This question is about what you do at recess and lunch time. In the past 7 days (last week) what did you usually do…

	Sat down (talking, reading, doing schoolwork)	Stood or walked around	Ran or played a little bit	Ran around and played quite a bit	Ran around and played hard most of the time	I do not have recess
at morning recess	☐	☐	☐	☐	☐	☐
at lunch recess	☐	☐	☐	☐	☐	☐
at afternoon recess	☐	☐	☐	☐	☐	☐

1-5 In the past 7 days, mark how often you were physically active (like played sports, danced, or played games in which you are very active) … (mark only one for each row)

	None	1 time last week	2 to 3 times last week	4 to 5 times last week	6 or more times last week
right after school?	☐	☐	☐	☐	☐
in the evenings?	☐	☐	☐	☐	☐
on the last weekend?	☐	☐	☐	☐	☐

1-6 Which one of the following describes you best for the last 7 days? Read all five statements before deciding on the one that describes you.

- All or most of my free time was spent doing things that involve little physical effort.
- I sometimes (1-2 times last week) did physical things in my free time (e.g., played sports, went running, swimming, bike riding, did aerobics).
- I often (3-4 times last week) did physical things in my free time.
- I quite often (5-6 times last week) did physical things in my free time.
- I very often (7 or more times last week) did physical things in my free time.

1-7 Mark how often you were physically active (like played sports, games or danced) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday	☐	☐	☐	☐	☐
Tuesday	☐	☐	☐	☐	☐
Wednesday	☐	☐	☐	☐	☐
Thursday	☐	☐	☐	☐	☐
Friday	☐	☐	☐	☐	☐
Saturday	☐	☐	☐	☐	☐
Sunday	☐	☐	☐	☐	☐

1-8 Were you sick last week, or did anything prevent you from doing your normal physical activities? (mark one)

- ○ Yes
- ○ No

1-9 Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (mark only one circle per row)

Activity	No	1-2 times	3-4 times	5-6 times	7 + times
Skipping/jumping rope	☐	☐	☐	☐	☐
Rollerblading	☐	☐	☐	☐	☐
Active games (tag)	☐	☐	☐	☐	☐
Walking for exercise	☐	☐	☐	☐	☐
Bicycling	☐	☐	☐	☐	☐
Jogging or running	☐	☐	☐	☐	☐
Swimming laps	☐	☐	☐	☐	☐
Baseball, softball	☐	☐	☐	☐	☐
Dance (classes, social, recreational)	☐	☐	☐	☐	☐
Football	☐	☐	☐	☐	☐
Racket sports (badminton, tennis, racket ball)	☐	☐	☐	☐	☐

Activity	No	1-2 times	3-4 times	5-6 times	7 + times
Skateboarding	☐	☐	☐	☐	☐
Soccer	☐	☐	☐	☐	☐
Volleyball	☐	☐	☐	☐	☐
Hockey (roller, ice, street, field)	☐	☐	☐	☐	☐
Basketball	☐	☐	☐	☐	☐
Ice skating	☐	☐	☐	☐	☐
Cross-country skiing, downhill skiing or snowboarding	☐	☐	☐	☐	☐
Martial arts (karate, judo)	☐	☐	☐	☐	☐
Gymnastics	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐

1-10 Do you participate in before school, noon hour, or after school physical activities organized by your school (i.e. intramurals, school team sports)

- Yes
- No
- None offered

1-11 In the past 12 months, how often have you played sports or done physical activity WITHOUT a coach or instructor present (i.e. biking, skateboarding, rollerblading, road hockey, hiking, etc)

- Never
- Less than once/week
- 1-3 times/week
- 4 or more times/week

1-12 Do you participate in competitive or non-competitive sport/physical activity NOT organized by your school? (i.e YMCA leagues, tennis/golf lesson)

- Yes
- No

1-13 During the past school week, how many days did you get to and from school actively (i.e. walk, bike, skateboard)

- 0 days
- 1 day

- 2 days
- 3 days
- 4 days
- 5 days

1-14 Usually, how many hours per day do you spend on the following activities outside of school hours?

	Less than 1 hour a day	1-2 hours a day	3-4 hours a day	5 or more hours a day
Using a computer	☐	☐	☐	☐
Playing video games	☐	☐	☐	☐
Watching TV	☐	☐	☐	☐
Using a cell phone, tablet, or iPad®	☐	☐	☐	☐

1-15 How strongly do you agree with the following statements?

For these questions, we define "physically active" as activities you do for at least 20 minutes that make you breathe harder.

Being physically active influences or affects…	**Not at all**	**A little bit**	**Quite a lot**	**Very much**
your health	☐	☐	☐	☐
your body weight	☐	☐	☐	☐
how well you do in school	☐	☐	☐	☐
The type of food you eat influences or affects …	Not at all	A little bit	Quite a lot	Very much
your health	☐	☐	☐	☐
your body weight	☐	☐	☐	☐
how well you do in school	☐	☐	☐	☐

1-16 At about what time do your parents/guardians usually expect you to get into bed …

	Before 8 pm	8-8:30 pm	8:30-9 pm	9-9:30 pm	9:30-10 pm	10-10:30 pm	After 10:30 pm	No bedtime
during the week	☐	☐	☐	☐	☐	☐	☐	☐
during the weekend	☐	☐	☐	☐	☐	☐	☐	☐

1-17 In the hour before you go to sleep, how often do you do the following activities *in your bedroom*?

	Never or almost never	About once per month	Between 1 and 3 times a week	Once per night on most nights	Several times in a night on most nights
Read books?	☐	☐	☐	☐	☐
Watch television and/or DVDs?	☐	☐	☐	☐	☐
Use a computer and/or laptop?	☐	☐	☐	☐	☐
Use a tablet or iPad?	☐	☐	☐	☐	☐
Play video games?	☐	☐	☐	☐	☐
Use a cell phone?	☐	☐	☐	☐	☐

1-18 How much do you care about:

	Not at all	A little bit	Quite a lot	Very much
being physically active?	☐	☐	☐	☐
eating healthy foods?	☐	☐	☐	☐
going to sleep on time?	☐	☐	☐	☐
being healthy?	☐	☐	☐	☐

1-19 These questions are about how confident you feel about doing certain activities.

How confident are you that you could do the following things on your own time outside of school hours?	Not at all confident	A little bit confident	Quite confident	Very confident
Be physically active no matter how tired you may be	☐	☐	☐	☐
Be physically active even if you have a lot of homework	☐	☐	☐	☐
Ask your parent or other adult to play a physical activity or sport with you	☐	☐	☐	☐
Be physically active most days of the week	☐	☐	☐	☐
How confident are you that you could …	Not at all confident	A little bit confident	Quite confident	Very confident
go to bed on time?	☐	☐	☐	☐

1-20 How often do you buy or are you served something to eat or drink at school?

- ○ Never or almost never
- ○ Once in a while
- ○ 1-2 times a week
- ○ 3 or more times a week

1-21 When you buy or are served food or drink at school, what do you usually get? (Fill in all that apply)

	Never	Less than once a week	1-2 times a week	3 + times a week
Bottled water	☐	☐	☐	☐
White milk	☐	☐	☐	☐
Flavoured milk and yogurt drinks like chocolate milk, Yop, etc.	☐	☐	☐	☐
Juice	☐	☐	☐	☐
Pop	☐	☐	☐	☐
Soup, sandwiches or burritos	☐	☐	☐	☐
Hot dogs, corn dogs, pizza, hamburgers	☐	☐	☐	☐

Snacks like donuts, candy, chocolate bars, chips, etc.	☐	☐	☐	☐
Healthy snacks like fruit, vegetables, plain popcorn, peanuts, etc.	☐	☐	☐	☐

1-22 When you choose a drink at school, home, or elsewhere, how often do you choose …

	Never	Less than once a week	1-2 times a week	3 + times a week
Sport drinks like Gatorade, Powerade	☐	☐	☐	☐
Energy drinks like Red Bull	☐	☐	☐	☐

1-23 When at home, how often do you help prepare or cook…

(In this question, preparing meals does not include nonfood-related activities such as setting the table.)

	Never / less than once per week	1-2 times per week	3-4 times per week	5 or more times per week
Breakfast	☐	☐	☐	☐
Lunch	☐	☐	☐	☐
Dinner / supper	☐	☐	☐	☐
Snacks	☐	☐	☐	☐

1-24 When you help prepare or cook food in your home, how often do you…

	Never	Sometimes	Always
Help chop or cut food	☐	☐	☐
Use the stove	☐	☐	☐
Use the oven	☐	☐	☐
Use the microwave	☐	☐	☐

1-25 When you help prepare or cook food in your home, how often do you prepare the following types of food?

	Never	Sometimes	Always
Fruits	☐	☐	☐
Vegetables	☐	☐	☐

Ready-made foods (including frozen dinners, canned foods)	☐	☐	☐
Sweet foods / snacks (including cookies, cakes, pies)	☐	☐	☐

Section 2: Your health and lifestyle

2 Please read the following statements and choose the answer that best describes you.

	Never or rarely	Sometimes	Regularly	Most of the time	Always	Unsure
You do the right thing without being asked	☐	☐	☐	☐	☐	☐
You set goals and plan ahead	☐	☐	☐	☐	☐	☐
You do your homework before play	☐	☐	☐	☐	☐	☐
You try to find solutions when others don't agree with you	☐	☐	☐	☐	☐	☐
You listen when others are talking to you	☐	☐	☐	☐	☐	☐
You work well in groups	☐	☐	☐	☐	☐	☐
You take care of your healthy by choosing healthy snacks	☐	☐	☐	☐	☐	☐
You take care of your health by exercising	☐	☐	☐	☐	☐	☐
You take care of your health by getting enough sleep	☐	☐	☐	☐	☐	☐

Section 3: **Alberta Health and Wellness programs**

Alberta Health has developed some TV advertisements, posters, internet sites, magnets and other material.

3-1 Have you heard of or seen any of the following? (Fill in all that apply)

Thank you for your help!

Please put the survey in the envelope and one of the evaluation assistants will collect it.

To be filled out by evaluation assitant

Height	____	____	_____	.	_____	_____ cm
0	O	O	O		O	O
1	O	O	O		O	O
2	O	O	O		O	O
3	O	O	O		O	O
4	O	O	O		O	O
5	O	O	O		O	O
6	O	O	O		O	O
7	O	O	O		O	O
8	O	O	O		O	O
9	O	O	O		O	O
Weight	____	____	_____	.	_____	_____ kg
0	O	O	O		O	O
1	O	O	O		O	O
2	O	O	O		O	O
3	O	O	O		O	O
4	O	O	O		O	O
5	O	O	O		O	O
6	O	O	O		O	O
7	O	O	O		O	O
8	O	O	O		O	O
9	O	O	O		O	O
Pedometer Score		____	____	____	____	____
	0	O	O	O	O	O
	1	O	O	O	O	O
	2	O	O	O	O	O

3	O	O	O	O	O
4	O	O	O	O	O
5	O	O	O	O	O
6	O	O	O	O	O
7	O	O	O	O	O
8	O	O	O	O	O
9	O	O	O	O	O
Gender	O1	O2			