University of Alberta

Physical Activity in the Era of the Childhood Obesity Epidemic: Patterns, Determinants, and Effective Health Promotion Programs

by

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A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Epidemiology

Department of Public Health Sciences

Abstract

Physical activity is important for obesity prevention. Given that the prevalence of obesity among Canadian children has substantially increased over recent decades, and that obesity has substantial consequences for health and wellness, physical activity promotion continues to be a priority for public health. This thesis research aims to further our understanding of children's behavioural patterns where they relate to physical activity and obesity. It also aims to identify factors and effective strategies that increase physical activity among children. These aims were assessed through six interconnected research papers. In the first paper we demonstrated that consideration should be given to activities not captured by pedometers as adjusting crude pedometer-measured steps for these activities substantially improved the ability to accurately assess children's physical activity levels, and to identify children who were obese. In the second paper we revealed that policy makers should consider targeting physical activity in girls, and outside of school as these variables and time periods were characterized by low activity. In the third and fourth papers we showed that parental beliefs and support for physical activity were positively related to children's physical activity achieved on weekend days, and negatively associated with childhood overweight. In the fifth paper we demonstrated that school programs that support physical activity through positive environments,

curriculum, policy, and partnerships lead to improvements in children's physical activity both during and beyond school. In the last paper, we revealed that programs implemented in schools located in disadvantaged neighbourhoods reduced inequalities in physical activity. Furthermore, we found that although the programs were implemented school-wide and did not specifically target student subgroups, they were effective in increasing physical activity relatively evenly among low-active, active, and high-active students. Likewise they relatively evenly reached normal weight and overweight students, and those of distinct socioeconomic backgrounds. The results of this thesis provide researchers and policy makers with new evidence on important determinants of physical activity in children from an Albertan context. They also underline the importance of supporting strategies for physical activity promotion and specifically school health programs as these improve physical activity, reduce obesity prevalence rates and diminish health inequalities.

Acknowledgements

First and foremost, I would like to sincerely thank my supervisor and mentor, Dr. Paul Veugelers. Paul, I have benefited tremendously from your encouragement, support, and invaluable guidance over the course of my graduate program. I am incredibly grateful to have had the opportunity to learn from you; it has enriched my life immensely. Thank you for a truly exceptional experience.

I would also like to thank my supervisory committee members, Drs. Katerina Maximova and Jonathan McGavock for their endless support and guidance. Our lively discussions during committee meetings taught me to think critically and inspired the focus of this thesis. Thank you for sharing your wealth of knowledge and encouraging me to become a well-rounded researcher.

For their time, commitment, and constructive critiques of this research, I wish to sincerely thank the examining committees at my candidacy exam, Drs. Sentil Senthilselvan and Normand Boulé, and (in advance) at my thesis defense, Drs. Ian Janssen and Lory Laing.

To the remarkable members of the Population Health Intervention Research Unit at the School of Public Health, University of Alberta, I feel very fortunate to have been part of such an amazing team. My grateful thanks to Drs. Kate Storey and Stefan Kuhle for their helpful advice and reassurance during moments of stress. To Dr. Yen Li Chu, I am particularly grateful for your patience, support, and friendship throughout my doctoral journey. To Andrea Cliff, thank you for giving your time and help so generously. I would also like to extend thanks to the children and parents who participated in the Raising health Eating and Active Living (REAL) Kids Alberta and pedometer studies, and to the wonderful REAL Kids Alberta team.

Finally, I would like to extend a very special thank you to my friends and family. Mom and Dad, thank you so very much for your unconditional support and encouragement in everything I do. You've always had absolute confidence in me and I would not be where I am today without you. To my sisters, thank you for your support, friendship, and laughter. To my fiancé Ryan, thank you for your tremendous support, understanding, encouragement, and endless patience. You keep me balanced and bring such joy and laughter into my life. I feel unbelievably privileged to have you all in my life.

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Abbreviations

APPLE Schools	Alberta Project Promoting active Living and healthy Eating in Schools
AUC	Area under the curve
AVHPS	Annapolis Valley Health Promoting Schools
BMI	Body Mass Index
CANPLAY	Canadian Physical Activity Levels Among Youth
CATCH	Coordinated Approach to Children's Health
CHMS	Canadian Health Measures Survey
CI	Confidence interval
CSH	Comprehensive School Health
HEAL	Healthy eating and active living
MET	Metabolic equivalent task
MVPA	Moderate-to-vigorous physical activity
NHANES	National Health and Nutrition Examination Survey
OR	Odds ratio
PA	Physical activity
PAQ-C	Physical Activity Questionnaire for older Children
REAL Kids Alberta	Raising healthy Eating Active Living Kids in Alberta
ROC	Receiver Operating Characteristic
SD	Standard deviation
SE	Standard error
SES	Socioeconomic status
SHF	School Health Facilitator
TAAG	Trial of Activity for Adolescent Girls
US	United States
WHO	World Health Organization

1 Introduction

Over the past three decades the prevalence of overweight and obesity has substantially increased worldwide.[1-3] While more pronounced in developed countries, the prevalence has also increased in low- and middle-income countries.[1-3] Obesity is an important risk factor for several chronic diseases,[4-6] leads to a decreased quality of life[7] and life-expectancy,[6, 8] and places a significant financial burden on the health care system and the population's economic well-being.[9] As such, preventing obesity continues to be a priority for public health. The primary causative factor of excess body weight is a sustained imbalance between energy intake and energy expenditure.[10] Accordingly, lifestyle factors (i.e., healthy eating and active living (HEAL)) have been a focus of prevention and treatment efforts. Though, a complex web of underlying social and environmental factors complicates these efforts.[11, 12]

Childhood is a critical period for the development of overweight and obesity.[13] Obesity in childhood is associated with low self-esteem,[14] bullying, discrimination, victimization,[15-18] and academic performance.[19, 20] Furthermore, overweight children tend to become overweight adults.[21-23] Given these poor health outcomes, it is intuitive that health promotion initiatives for obesity prevention focus on young people. Reviews also demonstrate the tracking of healthy behaviours when established and practiced in childhood.[24, 25]

Given the relatively rapid increase in obesity among children, many researchers hypothesize that the causative or associated factors are more likely social and environmental than biological in nature.[26-29] Where this relates to children, characteristics of the home and school environments are particularly important[30] as this is where they spend the majority of their time. To better inform the development of policies and interventions aiming to improve HEAL behaviour for the prevention of obesity in children, it is important to understand, measure, and alter environments that promote or hinder these behaviours. This aligns with the objectives of this thesis research to further our understanding of the childhood obesity epidemic in Canada and the role that physical activity can play in obesity prevention.

This thesis begins with a summary of the current state of the evidence regarding the childhood obesity epidemic in Canada. This is followed by an in depth description of children's physical activity in the era of this epidemic. This includes the importance of physical activity for health, surveillance and measurement of physical activity, correlates and determinants of physical activity, the influence of parents on children's physical activity, and physical activity promotion in schools. Next the objectives and structure of this thesis research are presented, and finally, I provide a statement of my contributions to this thesis research.

1.1 Childhood obesity

1.1.1 Consequences

Obesity in childhood has substantial consequences for health and development. The increasing prevalence of obesity in children has lead to a higher prevalence of comorbid conditions such as high blood pressure, type II diabetes mellitus, orthopedic abnormalities, gallstones, asthma, and sleep apnea.[4, 6, 31, 32] Obese children are also more likely to experience body image issues, low self-esteem, teasing, victimization, discrimination, and decreased academic performance compared to their normal weight peers.[14-20, 33, 34] Because obesity in childhood tracks into adulthood,[22, 23] obese children are at greater risk of chronic disease later in life including cardiovascular disease, cancer, and osteoarthritis.[21, 35] The widespread short- and long-term consequences of childhood obesity lead to a decreased quality of life and life expectancy[36] to the extent that, for the first time, the current generation of children is expected to have a shorter lifespan than their parents.[37]

1.1.2 The unfolding epidemic

In Canada, the prevalence of overweight and obesity has substantially increased over the past decades. Between 1978/79 and 2004 the percentage of 2 to 17 year-olds classified as overweight or obese almost doubled (15% in 1978/79 to 26% in 2004).[38] Worse, the percentage classified as obese nearly tripled (3% in 1978/79 to 8% in 2004).[38] Data from the 2007-2009 Canadian Health Measures Survey (CHMS) indicate that 28% of children are now classified as overweight[39] and 9% obese.[40] Though the low-response rate to the recent CHMS may have lead to an underestimation of the actual proportions of overweight and obesity.

Among Canadian children, the prevalence of overweight and obesity is slightly greater among boys than girls (overweight: 27% of boys and 25% of girls; obese: 9% of boys and 7% of girls).[38] However, the increase in prevalence among boys and girls has been somewhat equal.[38, 39] Other vulnerable populations in Canada include children of low socioeconomic status (SES)[38, 41, 42] and Canadian Aboriginal children.[38, 43-46]

1.1.3 Healthy eating and active living

The primary causative factor of excess body weight is a sustained imbalance between energy intake and energy expenditure.[10] Accordingly, obesity is considered a lifestyle-related disease. Over the past three decades children have been increasingly faced with an abundance of convenient, appealing, nutrient-dilute foods that are relatively inexpensive, while opportunities for physical activity have diminished (e.g., reduced physical education class, recess time, neighbourhood safety, traffic) and those for inactive pursuits have increased e.g., television, computers, video games.[26, 27, 47, 48] As such, it has become increasingly difficult for children to achieve energy balance. While there has been much debate over their relative importance for obesity prevention,[47, 49, 50] reviews consistently demonstrate that the most effective obesity interventions promote both HEAL.[51-53]

1.1.4 Upstream risk factors

Lifestyle behaviours are often determined by upstream factors including SES. Usually measured by education and income, lower SES tends to be associated with poorer dietary habits and lower levels of physical activity. This association also exists among children,[41, 42, 54-56] possibly because parents are not aware or do not understand nutrition and physical activity guidelines or they cannot afford healthy foods or extracurricular physical activities for their children.

Environments can also determine lifestyle behaviours. Those that encourage the consumption of low quality foods and/or discourage physical activity are recognized as “obesogenic”.[26] Elements of “obesogenic” environments include low-walkability, unsafe neighbourhoods, limited playgrounds and access to sport and recreational facilities, easy access to elevators and escalators, high density of cars and fast-food outlets, and limited availability of healthy food options. “Obesogenic” environments are more commonly populated by families of low

SES, thereby increasing the risk of obesity among this group.[57] The relationship between SES, environments, and obesity support the notion that maintaining a healthy active lifestyle is determined more by life chances than choices.

1.1.5 Interventions

There are two overarching approaches to reversing the obesity epidemic: treatment and prevention. Treatment is the traditional approach to healthcare and involves "treating" or "intervening" among individuals diagnosed as overweight or obese.[58] Childhood obesity is commonly diagnosed based on body mass index (BMI) interpreted using age and sex adjusted cut-offs,[59] or percentiles,[60] waist circumference, or indices based on waist circumference, such as weight-to-height ratio.[61] Pediatric obesity treatments are generally designed to bring weight gain under control and tend to focus less on weight-loss.[62, 63] Lifestyle interventions with family involvement are the mainstay of weight management for children[4, 64] and involve a reduction in the intake of low-quality foods while maintaining or increasing physical activity. Other forms of treatment include pharmacotherapy or bariatric surgery,[4, 64] however these are considered for children only if intensive lifestyle modifications have failed and in the presence of comorbidities. Reviews support short-term benefits of lifestyle obesity treatments, but indicate that long-term weight management is difficult.[1, 62, 64-66]

Prevention is a public health, rather than clinical, approach to health, which aims to keep healthy children, healthy.[58] This approach involves preventing positive energy balance through small changes in diet and physical activity, while simultaneously addressing the environment to make it easier to make healthier choices. Obesity prevention interventions, particularly among children, are typically population-based, and therefore aim to lower the risk of overweight among the entire population.[58] Accordingly, the potential benefits are larger for the population than for individuals.[58] Population-based interventions are particularly favourable for obesity prevention as they reduce stigma that may occur when specific high-risk groups are targeted.[1, 58, 62] These interventions can be delivered through a variety of settings, yet most use family- or school-based approaches.[67-70] Family- and school-based interventions operate on the premise that education, social support, and environments are protective against excess weight. Although this premise cannot be refuted, affecting body weight in the long-term has proven exceedingly difficult to achieve.[1] Several reviews have concluded that most pediatric obesity interventions are marked by only small changes in target behaviours, and no significant effect on reducing overweight and obesity.[52, 71-73] The key to successful obesity prevention will be long-term adherence to a lifestyle characterized by HEAL behaviours.

Prevention is widely recognized as the best approach to reversing the obesity epidemic.[1, 12, 62, 63] However, because approximately one third of Canadian children and youth are overweight,[39] effective prevention of adult disease must include treatment of those already overweight. Therefore, obesity prevention and treatment are necessary to ensure the current and future health of children in Canada.

1.2 Physical activity

1.2.1 Importance

Physical activity is important for children's health and development. Regular physical activity contributes to cardiovascular fitness, strength, flexibility, and bone density.[74] Physical activity is associated with positive self-esteem,[75] improved academic and cognitive performance,[76-79] and reduced behavioural and mental health issues.[80, 81] Additionally, children who spend 60 minutes or more every day in moderate-to-vigorous physical activity (MVPA) are less likely to develop excess body weight and consequent chronic diseases.[74] Physical activity behaviour established in childhood and adolescents tracks into adulthood.[24]

1.2.2 Surveillance

In Canada, children and youth are recommended to accumulate at least 60 minutes of MVPA every day to obtain health benefits.[74] This translates to approximately 13,500 steps.[82-84] Accelerometer data from the Canadian Health Measures Survey (CHMS) indicate that children are not sufficiently active; less that 10% met these recommendations at least six days per week.[85] However, nearly 30% met these activity levels when averaged across valid days i.e., number of days when accelerometer/pedometer was worn for 10 or more hours. This suggests that children's day-to-day physical activity patterns vary greatly. Canadian children spend on average 54 minutes per day in MVPA, or take 11,224 steps.[85] Data from the Canadian Physical Activity Level Among Youth (CANPLAY) study report a similar proportion of children meeting step count recommendations and daily average steps.[86, 87] Both surveys also show that boys are more active than girls, and that daily steps decline by approximately 20% from the youngest (6 to 10 year olds) to oldest (15 to 19 year olds) age groups.[85-87]

1.2.3 Measurement

Physical activity is defined as any bodily movement resulting in energy expenditure.[88] The use of valid and reliable measures of movement is an important methodological consideration in physical activity epidemiological research. Accurate measurement is important to identify children who are most at risk of disease, and to monitor progress of interventions and changes in physical activity and overtime.[89] A variety of methods have been developed to assess the relationship between physical activity and these outcomes. The method should be suitable to measure physical activity over periods long enough achieve a representative estimate of normal daily behaviour, with minimal discomfort to the participants, and applicable to large populations.[90] Methods can broadly be divided into subjective and objective categories.

Subjective methods include direct observation, self- or proxy-reported questionnaires, dairies, and activity logs. Direct observation is useful to assess physical activity in controlled environments and for validation studies, while questionnaires, diaries, and activity logs are a frequently used in large scale, population-based studies. Subjective methods provide a practical and affordable means to assess physical activity,[91] though reporting bias may compromise their accuracy.[92] This limitation is particularly relevant when assessing physical activity among children due to lower cognitive development, and sporadic and varying physical activity behaviour.[93]

Objective methods include doubly labeled water (DLW), heart rate monitoring, and activity monitors i.e., accelerometers and pedometers. DLW and heart rate monitors provide valid and reliable estimates of physical activity,[94, 95] but significant limitations often make them inappropriate for use in large-scale studies under free-living conditions.[91, 95, 96] By contrast, activity monitors are one of the most commonly used methods to measure physical activity. These devices are small, unobtrusive, transportable, and require less time and financial and human resources to use compared with criterion measures such as DLW.[91] Several reviews have established accelerometers and pedometers as valid and reliable measures for assessing children's physical activity.[94, 97-99]

Accelerometers quantify physical activity by measuring the acceleration of movement. Accordingly, they provide an indication of the frequency, duration, and intensity of physical activity.[97] In many studies, accelerometry data are expressed as "movement counts", but unless translated into an estimate of activity intensity (i.e., minutes of MVPA per day) these movement counts seem of little value to policy makers or the public at large.[100] Despite this limitation, and their high costs, accelerometers have emerged as a focus in physical activity research.[97]

Pedometers quantify physical activity by detecting and counting the steps taken during ambulatory activities. For this reason they are generally worn at the waist. Though they can be worn elsewhere, (i.e., ankle or wrist) they tend to overestimate physical activity through the detection of "fidgeting" behaviours.[101] In addition to counting steps, some pedometers, albeit with less accuracy, can also estimate distance traveled and energy expenditure.[102] Some models have an internal memory which can store hourly and daily step count data for later downloading. This feature eliminates the need for participants to record their steps at the end of each day and therefore reduces a potential source of reporting bias.[103] Other models can also record and store data on periods of when the pedometer was worn. This feature can be used to measure wear-time, which is important to ensure the reliability of physical activity estimates.[104]

Pedometers use two mechanisms for recording steps. The most basic is a spring-suspended horizontal lever arm that moves up and down in response to vertical displacement of the waist.[102] With each step, the motion of the lever opens and closes an electronic circuit to record steps (e.g. Yamax Digiwalker). The more complex is a piezoelectric accelerometer with a horizontal beam that is weighted on one end.[102] The beam compresses a piezoelectric crystal when subjected to acceleration, thereby generating a voltage proportional to the acceleration. The voltage oscillations are used to record steps (e.g. Omron HJ-720).[69] Thus, this mechanism may be less susceptible to errors that occur due to tilt.

In contrast to accelerometers, pedometers are less expensive, easier to use, and produce a more user-friendly output.[98, 99] For these reasons, pedometry has gained grounds in both research and practice as a reasonable method to estimate physical activity.[86, 105]

Children's physical activity is characterized by considerable intra- and inter-individual variability. Accordingly, to obtain reliable estimates of children's physical activity, monitoring devices must for worn for a minimum number of hours per days and number of days. Recommendations indicate that the requirement for minimum wear time includes 8-10 hours for the minimum daily wear time[106] on at least three days, including at least one weekend day.[107]

Both accelerometers and pedometers are limited to the measurement of ambulatory activities i.e. walking, running. Consequently, they do not accurately capture activity gained through non-ambulatory activities including biking, skating, and skiing. There are also activities where safety regulations or discomfort restrict activity monitors from being worn e.g. soccer, martial arts, gymnastics. Furthermore, most accelerometers and pedometers are not waterproof, and therefore cannot be worn during water-based activities like swimming. This “non-wear time” leads researchers to significantly underestimate actual physical activity levels, which leads to underestimating the proportion of study participants meeting physical activity recommendations, and herewith biased estimates of the proportion at risk for chronic diseases.[83, 108-110] Currently, there is no established best practice approach to deal with energy expended during periods when activity monitors are not or cannot be worn.

Selecting the most appropriate method to measure physical activity depends on the dimension(s) of physical activity of interest (i.e., intensity, frequency, duration, total volume); the study objectives, characteristics of the target population, and study feasibility in terms of cots and logistics.[89]

1.2.4 Correlates and determinants

There is a substantial literature base examining factors that are associated with physical activity among children, and it has been reviewed several times.[111-114] These factors can be organized into three distinct levels, which broadly include individual, social, and environmental factors.

Within the individual, the established demographic determinants include age, and gender.[111-115] Boys are consistently more active than girls. Based on normative data, Tudor-Locke et al reported that boys average 12,000 to 16,000 steps per day while girls average 10,000 to 13,000.[84] Furthermore mean steps per day are generally highest before the age of 12 and decreases through adolescence until mean values of approximately 8,000 to 9,000 steps per day are observed in young adults.[84] Other factors at the individual level include psychosocial variables including, perceived competence, self-efficacy, attitude, perceived behavioural control, value of health, barriers to physical activity, and previous physical activity. In a review of review papers, however, self-efficacy and previous physical activity were the only established determinants of children's physical activity.[112]

At the social or interpersonal level, children's physical activity is determined by SES, whereby children whose parents are more highly educated and/or from households with higher income are more physically active.[30, 113, 115, 116] Ethnicity is also an established determinant.[115, 117] Parents have also been identified as important factors at the social level. Recently, Trost and Loprinzi[118] evaluated 103 studies that examined the influence of parental physical activities, parental support for child physical activity, parenting style, and family cohesion on child activity behaviours. Results showed that parental support was the only established determinant.[118] Other reviews support this finding.[112, 113, 115, 116, 119]

Attributes within the environment also influence children's physical activity. An important environmental factor for children's activity is the school environment. Schools are important because they provide structured opportunities for physical activity throughout the day. However, the associations between children's physical activity achieved on school days relative to that on non-school days, and during school hours relative to non-school hours are unclear. While some studies report significantly higher levels of physical activity on school days[86, 120-123] others do not.[124-126] Similarly, some studies report higher activity levels during school[88, 121, 122] and others report higher levels outside of school.[124, 126] It is believed that the variability in physical activity levels on school days and non-school days, and during school hours and non-school hours relates to a number of factors that are not well understood e.g. age, culture, involvement in sports.[127]

The relationships between physical activity other environmental factors are clearer than those for schools. Reviews show that the most supported correlates for children include walkability, traffic speed/volume (inverse), safety, access/proximity to recreation facilities, lane-use mix, residential density, and the home environment.[30, 128-131]

1.3 Parental influences on children's physical activity

It is well established that parents play a significant role in shaping the physical activity behaviours of their children. Parents can influence their children's physical activity in a variety of ways including, encouragement, social support, involvement, facilitation or restriction of physical activity, and direct modeling. Several reviews have assessed parental influences on activity levels in children.[30, 113, 118, 119, 132, 133] These studies provide evidence for the key role parents play in promoting or deterring activity levels in their children.

Parental beliefs and support for physical activity have been suggested as key areas for health promotion. Schools provide an important avenue for parenting research as they offer an opportunity to reach parents/families through their children. Several reviews indicate that involving family components enhances the effectiveness of interventions delivered in the school setting.[51, 53, 134-136] Yet, few have seized this opportunity e.g., 3 of 57 interventions reviewed by Salmon et al. included parental involvement in physical activity interventions.[136] Parents can be included in interventions through policy, curricula, and environmental components. Incorporating a family component in school-based interventions helps to ensure that HEAL behaviours are equally as supported at home as they are at school.

1.4 Promoting physical activity in school

Schools represent an attractive setting for physical activity promotion and obesity prevention for several important reasons. First, schools have the ability to reach nearly all children who spend a significant proportion of their time there from the ages of 5 to 18. Second, they have existing facilities and personnel needed to teach and promote healthy lifestyles, which can help children establish lifelong healthy behaviours.[24, 137] Third, schools provide a setting to deliver health information to the whole school environment.[69, 70, 138]

School-based interventions can be simple or multidimensional, applying educational, cognitive, behavioural, environmental, parental and/or social support strategies to promote HEAL behaviours. Educational components are part of most school-based interventions,[52] while few incorporate elements of home and/or community involvement e.g., 3 of 57 interventions reviewed by Samlon et al.[136] Incorporating these elements is important as parents greatly influence children's physical activity outside of school (e.g.[118, 139, 140]). Furthermore, reviews demonstrate that incorporating family components enhances the effectiveness of interventions delivered in school.[51, 53, 134-136, 141]

The World Health Organization (WHO) recommends that schools use a comprehensive approach for health promotion.[142] This approach, known in Canada as Comprehensive School Health (CSH), is multifaceted and involves parents, communities, and stakeholders to provide supportive policies, programs, and environments in the whole school community.[138] Based on the *Ottawa Charter for Health Promotion*, the CSH framework addresses actions in four interrelated pillars: 1) teaching and learning; 2) physical and social environments; 3) healthy school policy; 4) partnerships and services. To realize

CSH, actions within all four pillars must be implemented.[142]

Annapolis Valley Health Promoting Schools (AVHPS)[143] and 'Action Schools! BC'[144] are flagship examples of CSH and are associated with increased levels of physical activity and in the AVHPS model, lower body weights. In the United States, the Coordinated Approach to Children's Health (CATCH)[145] and the Trial of Activity for Adolescent Girls (TAAG)[146] also deliver multifaceted programs and demonstrated increases in children's physical activity. Recently, Fung et al.[147] reported on the success of CSH in the Alberta Project Promoting active Living and healthy Eating in Schools (APPLE Schools). Two years from baseline, children attending APPLE Schools were less likely to be obese, and reported to be more active relative to children attending other schools.

A key objective of CSH is to foster positive health behaviours beyond the school environment.[138] Most studies to date, however, have quantified the effectiveness of school programs in terms of mean daily physical activity levels or physical activity accumulated during physical education (PE) and school time.[143-145, 147] Very few have extended their observations beyond school hours and school days – a period characterized by low physical activity in youth.[124, 125, 148-150] Studies on the impact of school-based interventions at specific times (i.e. during school hours or after school hours) and on specific days (i.e. school days or weekends) are most informative to this key objective of CSH.[138] This information is also important to determine critical windows to further tailor and enhance health promotion initiatives in schools.

Most school-based programs are population-based, and therefore are designed to improve the average population health.[58] The concern has been raised that increases in physical activity attributable to such programs may stem from those students who are already active rather than from those who are less active or would otherwise benefit the most from health promotion. As such, the potential exists for school-based health promotion programs to in fact contribute to increases in inequalities in health. To overcome this "inequality paradox",[151] several studies have implemented programs in schools located in disadvantaged communities,[152-156] while others have used a targeted approach to tailor interventions to the characteristics of specific groups most at risk of poor health behaviours and outcomes.[146, 157-159] Some of these studies have reported increases in children's physical activity.[146, 152, 154, 156, 158] However, because these studies used equally disadvantaged schools as control groups, there is a lack of evidence regarding how these programs fare in comparison to more advantaged groups. Furthermore, to our knowledge there is no evidence regarding the distribution of program effects among children of various levels of activity, and health and socioeconomic positions. Physical activity interventions that benefit all children equally may provide an important route for bridging the gap in health between lower and higher socioeconomic groups.

1.5 Objectives

This thesis is epidemiologic in nature and follows a population health approach. As such, it aims to assess behavioural patterns related to physical activity and obesity in children. It also aims to identify factors and strategies that promote increased physical activity among children for the prevention of obesity. Specifically, the objectives of this thesis research are to 1) assess physical activity patterns of grade 5 children; 2) assess the relationships of parental influences and children's activity levels and body weight status; and 3) assess the importance of school-based health promotion for children's physical activity and its impact on health inequalities. Data were collected from grade 5 students and parents in Alberta, Canada using rigorous study designs and protocols. Analyses are adjusted for the clustering of students within schools and for potential confounders. Details on design and analyses are provided in the regarding chapters.

1.6 Structure of this thesis

This thesis uses a "paper-based" format and includes an introduction, six manuscripts which align with the research objectives, and a general discussion. The introduction provides a summary of the current literature and evidence on the surveillance and determinants of childhood obesity and the role that healthy eating and active living play in the obesity epidemic. The measurement and determinants of physical activity are also introduced and discussed, in addition to the influence that parents have on their children's activity levels, and potential and on-going interventions to improve physical activity behaviours and reduce health inequalities among children.

Six research papers are situated within subsequent chapters. The first two manuscripts address the first objective. Specifically, the first manuscript compares the ability of four physical activity measures, including a novel approach, which incorporates information from activity diaries into pedometer measured steps, to identify school-aged children at risk of overweight and obesity. The hypothesis to be tested is whether incorporating information from activity diaries into pedometer-measured steps would improve the ability to correctly classify children with excess body weight. The second manuscript describes children's physical activity patterns over the course of a typical week, on school and non-school days, and during and beyond school hours. Here, I hypothesize that children's physical activity would be lowest during the windows of time that children were at school.

Manuscripts three and four address objective two. Specifically, manuscript three assesses the relationship of parental beliefs and support with physical activity, and whether this association is distinct for normal weight compared to overweight children. My hypotheses for this manuscript are that parental beliefs and support for physical activity are positively associated with children's physical activity, and that parental beliefs and support for physical activity are negatively associated with excess body weight in children. Manuscript four explores this relationship using an objective measure of children's physical activity and aims to determine if parental correlates of children's physical activity are different for school days than for weekend days. Here, I tested the hypotheses that parental beliefs and support for physical activity are positively associated with physical activity levels in children on school days and weekend days and that the association is distinct for school days and weekend days.

The remaining two manuscripts address objective three. Specifically, manuscript five assesses the impact of school-based health promotion on children's pedometer measured physical activity during and beyond school hours. In this manuscript I test the hypothesis that compared to children receiving standard curriculum, children in schools implementing health promotion initiatives would display significantly higher levels of physical activity, particularly outside of school hours. The final manuscript compares the two-year change in physical activity among low-active, active, and high-active grade five students attending schools with and without health promotion programs, and examines whether health promotion is equally effective among those who would benefit the most from health promotion. My hypothesis is that increases in physical activity would be more pronounced among children attending schools implementing health promotion programs than among those students from non-program schools, and that these increases would be greatest among the sub-groups of students most "in need" of health promotion, specifically those who are low-active, overweight, from low-income households, or whose parents are low-educated.

Following the six manuscripts is a general discussion and conclusion. This chapter includes a summary of the key findings, overall strengths and limitations, public health implications, and directions for future research.

1.7 Statement of contributions

The data for this thesis were collected using the Raising healthy Eating and Active Living Kids Alberta (REAL Kids Alberta) survey, funded by Alberta Health. The survey is lead by Dr. Paul Veugelers and aims to evaluate the Healthy Weights initiative implemented by Alberta Health. The survey is also used to evaluate the Alberta Project Promoting active Living and healthy Eating in Schools (APPLE Schools). In 2009, time-stamped pedometers were included in the APPLE Schools evaluation to provide an objective measure of grade 5 students' physical activity. I proposed to identify and collected pedometer data from 20 non-APPLE Schools located in the City of Edmonton and surrounding area. This allowed us to establish a control group for the analysis of the change in students' physical activity attributable to the APPLE Schools program. I was responsible for developing the protocol and leading the pedometer data collection and analyses. This included developing a pedometer activity diary for students to record their daily physical activity behaviour during periods of pedometer data collection, as well as the methods for incorporating this information into crude pedometer-measured steps.

I was responsible for identifying the research questions and conceptualizing the analytic approach of each of the studies in this thesis. I was responsible for the complex statistical analyses. I was further the primary author of each of the studies included in this thesis.

1.8 References

1. Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. *Lancet*. 2002;360 (9331):473-482.
2. Han JC, Lawlor DA, Kimm SY. Childhood obesity. *Lancet*. 2010;375 (9727):1737-1748.
3. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. *Int J Pediatr Obes*. 2006;1 (1):11-25.
4. Daniels SR, Jacobson MS, McCrindle BW, Eckel RH, Sanner BM. American Heart Association Childhood Obesity Research Summit: executive summary. *Circulation*. 2009;119 (15):2114-2123.
5. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics*. 1999;103 (6 Pt 1):1175-1182.
6. Must A, Strauss RS. Risks and consequences of childhood and adolescent obesity. *Int J Obes Relat Metab Disord*. 1999;23 Suppl 2 S2-11.
7. Kolotkin RL, Meter K, Williams GR. Quality of life and obesity. *Obes Rev*. 2001;2 (4):219-229.
8. Flegal KM, Kit BK, Orpana H, Graubard BI. Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. *JAMA*. 2013;309 (1):71-82.
9. Lehnert T, Sonntag D, Konnopka A, Riedel-Heller S, Konig HH. Economic costs of overweight and obesity. *Best Pract Res Clin Endocrinol Metab*. 2013;27 (2):105-115.
10. Dietz WH, Gortmaker SL. Preventing obesity in children and adolescents. *Annu Rev Public Health*. 2001;22 337-353.
11. Finegood DT, Merth TD, Rutter H. Implications of the foresight obesity system map for solutions to childhood obesity. *Obesity (Silver Spring)*. 2010;18 Suppl 1 S13-S16.
12. Kumanyika SK. Minisymposium on obesity: overview and some strategic considerations. *Annu Rev Public Health*. 2001;22 293-308.
13. Dietz WH. Critical periods in childhood for the development of obesity. *Am J Clin Nutr*. 1994;59 (5):955-959.
14. De Niet JE, Naiman DI. Psychosocial aspects of childhood obesity. *Minerva Pediatr*. 2011;63 (6):491-505.

15. Janssen I, Craig WM, Boyce WF, Pickett W. Associations between overweight and obesity with bullying behaviors in school-aged children. *Pediatrics*. 2004;113 (5):1187-1194.

16. Puhl RM, Heuer CA. The stigma of obesity: a review and update. *Obesity*. 2009;17 (5):941-964.

17. Robinson S. Victimization of obese adolescents. *J Sch Nurs*. 2006;22 (4):201-206.

18. Sentenac M, Arnaud C, Gavin A, Molcho M, Gabhainn SN, Godeau E. Peer victimization among school-aged children with chronic conditions. *Epidemiol Rev*. 2012;34 (1):120-128.

19. Burkhalter TM, Hillman CH. A narrative review of physical activity, nutrition, and obesity to cognition and scholastic performance across the human lifespan. *Advances in Nutrition: An International Review Journal*. 2011;2 (2):201S-206S.

20. Taras H, Potts-Datema W. Obesity and student performance at school. *J School Health*. 2005;75 (8):291-295.

21. Dietz WH. Overweight in childhood and adolescence. *N Engl J Med*. 2004;350 (9):855-857.

22. Herman KM, Craig CL, Gauvin L, Katzmarzyk PT. Tracking of obesity and physical activity from childhood to adulthood: the Physical Activity Longitudinal Study. *Int J Pediatr Obes*. 2009;4 (4):281-288.

23. Singh AS, Mulder C, Twisk JW, van Mechelen W, Chinapaw MJ. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev*. 2008;9 (5):474-488.

24. Jones RA, Hinkley T, Okely AD, Salmon J. Tracking physical activity and sedentary behavior in childhood: a systematic review. *Am J Prev Med*. 2013;44 (6):651-658.

25. Telama R. Tracking of physical activity from childhood to adulthood: a review. *Obes Facts*. 2009;2 (3):187-195.

26. Hill JO, Peters JC. Environmental contributions to the obesity epidemic. *Science*. 1998;280 (5368):1371-1374.

27. Hill JO, Wyatt HR, Reed GW, Peters JC. Obesity and the environment: where do we go from here? *Science*. 2003;299 (5608):853-855.

28. Jeffery RW, Utter J. The changing environment and population obesity in the United States. *Obes Res*. 2003;11 Suppl 12S-22S.

29. Peters JC, Wyatt HR, Donahoo WT, Hill JO. From instinct to intellect: the

challenge of maintaining healthy weight in the modern world. *Obes Rev*. 2002;3 (2):69-74.

30. Ferreira I, van der Horst K, Wendel-Vos W, Kremers S, van Lenthe FJ, Brug J. Environmental correlates of physical activity in youth - a review and update. *Obes Rev*. 2007;8 (2):129-154.

31. Freedman DS, Mei Z, Srinivasan SR, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. *J Pediatr*. 2007;150 (1):12-17.e2.

32. Maximova K, Kuhle S, Davidson Z, Fung C, Veugelers PJ. Cardiovascular Risk Factor Profiles of Normal and Overweight Children and Adolescents: Insights From the Canadian Health Measures Survey. *Can J Cardiol*. 2012

33. Harriger JA, Thompson JK. Psychological consequences of obesity: weight bias and body image in overweight and obese youth. *Int Rev Psychiatry*. 2012;24 (3):247-253.

34. Tremblay MS, Inman JW, Willms JD. The relationship between physical activity, self-esteem, and academic achievement in 12-year-old children. *Pediatr Exerc Sci*. 2000;12 (3):312-323.

35. Must A, Jacques PF, Dallal GE, Bajema CJ, Dietz WH. Long-term morbidity and mortality of overweight adolescents: a follow-up of the Harvard Growth Study of 1922 to 1935. *N Engl J Med*. 1992;327 (19):1350-1355.

36. Schwimmer JB, Burwinkle TM, Varni JW. Health-related quality of life of severely obese children and adolescents. *JAMA*. 2003;289 (14):1813-1819.

37. Olshansky SJ, Passaro DJ, Hershow RC et al. A potential decline in life expectancy in the United States in the 21st century. *N Engl J Med*. 2005;352 (11):1138-1145.

38. Shields M. Overweight and obesity among children and youth. *Health Rep*. 2006;17 (3):27-42.

39. Tremblay MS, Shields M, Laviolette M, Craig CL, Janssen I, Connor Gorber S. Fitness of Canadian children and youth: results from the 2007-2009 Canadian Health Measures Survey. *Health Rep*. 2010;21 (1):7-20.

40. Canada S, Burwinkle TM, Varni JW. Canadian Health Measures Survey: Body composition and fitness.

41. Achat HM, Stubbs JM. Socio-economic and ethnic differences in the prevalence of overweight and obesity among school children. *J Paediatr Child Health*. 2012

42. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry*.

2012;24 (3):176-188.

43. Belanger-Ducharme F, Tremblay A. Prevalence of obesity in Canada. *Obes Rev*. 2005;6 (3):183-186.

44. Bernard L, Lavallee C, Gray-Donald K, Delisle H. Overweight in Cree schoolchildren and adolescents associated with diet, low physical activity, and high television viewing. *J Am Diet Assoc*. 1995;95 (7):800-802.

45. Katzmarzyk PT. Obesity and physical activity among Aboriginal Canadians. *Obesity (Silver Spring)*. 2008;16 (1):184-190.

46. Ng C, Marshall D, Willows ND. Obesity, adiposity, physical fitness and activity levels in Cree children. *Int J Circumpolar Health*. 2006;65 (4):322-330.

47. Katz DL. Unfattening our children: forks over feet. *Int J Obes (Lond)*. 2011;35 (1):33-37.

48. Swinburn B, Egger G. Preventive strategies against weight gain and obesity. *Obes Rev*. 2002;3 (4):289-301.

49. Fox KR. Childhood obesity and the role of physical activity. *J R Soc Promot Health*. 2004;124 (1):34-39.

50. Millward DJ. Energy balance and obesity: a UK perspective on the gluttony v. sloth debate. *Nutr Res Rev*. 20131-21.

51. Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obes Rev*. 2009;10 (1):110-141.

52. Kamath CC, Vickers KS, Ehrlich A et al. Clinical review: behavioral interventions to prevent childhood obesity: a systematic review and metaanalyses of randomized trials. *J Clin Endocrinol Metab*. 2008;93 (12):4606-4615.

53. Katz DL. School-based interventions for health promotion and weight control: not just waiting on the world to change. *Annu Rev Public Health*. 2009;30 253-272.

54. Di Cesare M, Khang YH, Asaria P et al. Inequalities in non-communicable diseases and effective responses. *Lancet*. 2013;381 (9866):585-597.

55. Freedman DS, Ogden CL, Flegal KM, Khan LK, Serdula MK, Dietz WH. Childhood overweight and family income. *Med Gen Med*. 2007;9 (2):26.

56. Lynch JW, Kaplan GA, Salonen JT. Why do poor people behave poorly?

Variation in adult health behaviours and psychosocial characteristics by stages of the socioeconomic lifecourse. *Soc Sci Med*. 1997;44 (6):809-819.

57. Reidpath DD, Burns C, Garrard J, Mahoney M, Townsend M. An ecological study of the relationship between social and environmental determinants of obesity. *Health Place*. 2002;8 (2):141-145.

58. Rose G. Sick individuals and sick populations. *Int J Epidemiol*. 2001;30 (3):427-32; discussion 433.

59. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320 (7244):1240-1243.

60. Reilly JJ, Wilson ML, Summerbell CD, Wilson DC. Obesity: diagnosis, prevention, and treatment; evidence based answers to common questions. *Arch Dis Child*. 2002;86 (6):392-394.

61. McCarthy HD, Ellis SM, Cole TJ. Central overweight and obesity in British youth aged 11-16 years: cross sectional surveys of waist circumference. *BMJ*. 2003;326 (7390):624.

62. Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. *Obes Rev*. 2004;5 Suppl 1 4-104.

63. Schmitz MK, Jeffery RW. Public health interventions for the prevention and treatment of obesity. *Med Clin North Am*. 2000;84 (2):491-512, viii.

64. Mendez R, Grissom M. Disorders of childhood growth and development: childhood obesity. *FP Essent*. 2013;410 20-24.

65. Oude Luttikhuis H, Baur L, Jansen H et al. Interventions for treating obesity in children. *Cochrane Database Syst Rev*. 2009;1 (1

66. Whitlock EP, O'Connor EA, Williams SB, Beil TL, Lutz KW. Effectiveness of weight management interventions in children: a targeted systematic review for the USPSTF. *Pediatrics*. 2010;125 (2):e396-e418.

67. Candeias V, Armstrong TP, Xuereb GC. Diet and physical activity in schools: perspectives from the implementation of the WHO global strategy on diet, physical activity and health. *Can J Public Health*. 2010;101 Suppl 2 S28-S30.

68. Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting physical activity in children and youth: a leadership role for schools: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. *Circulation*. 2006;114 (11):1214-1224.

69. Stewart-Brown S. What is the evidence on school health promotion in improving health or preventing disease and, specifically, what is the effectiveness of the health promoting schools approach? 2006

70. Story M, Kaphingst KM, French S. The role of schools in obesity prevention. *Future Child*. 2006;16 (1):109-142.

71. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. *CMAJ*. 2009;180 (7):719-726.

72. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ*. 2012;345 e5888.

73. Sharma M. School-based interventions for childhood and adolescent obesity. *Obes Rev*. 2006;7 (3):261-269.

74. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7 40.

75. Mutrie N, Parfitt G. Physical activity and its link with mental, social and moral health in young people. *Young and active*. 199849-68.

76. Ahamed Y, Macdonald H, Reed K, Naylor PJ, Liu-Ambrose T, McKay H. School-based physical activity does not compromise children's academic performance. *Med Sci Sports Exerc*. 2007;39 (2):371-376.

77. Coe DP, Pivarnik JM, Womack CJ, Reeves MJ, Malina RM. Effect of physical education and activity levels on academic achievement in children. *Med Sci Sports Exerc*. 2006;38 (8):1515-1519.

78. Murray NG, Low BJ, Hollis C, Cross AW, Davis SM. Coordinated school health programs and academic achievement: a systematic review of the literature. *J Sch Health*. 2007;77 (9):589-600.

79. Sallis JF, McKenzie TL, Kolody B, Lewis M, Marshall S, Rosengard P. Effects of health-related physical education on academic achievement: project SPARK. *Res Q Exerc Sport*. 1999;70 (2):127-134.

80. Mahar MT, Murphy SK, Rowe DA, Golden J, Shields AT, Raedeke TD. Effects of a classroom-based program on physical activity and on-task behavior. *Med Sci Sports Exerc*. 2006;38 (12):2086-2094.

81. Pellegrini AD, Huberty PD, Jones I. The effects of recess timing on children's playground and classroom behaviors. *Am Edu Res J*. 1995;32 (4):845-864.

82. Adams MA, Johnson WD, Tudor-Locke C. Steps/day translation of the moderate-to-vigorous physical activity guideline for children and

adolescents. *Int J Behav Nutr Phys Act*. 2013;10 49.

83. Colley R, Connor Gorber S, Tremblay MS. Quality control and data reduction procedures for accelerometry-derived measures of physical activity. *Health Rep*. 2010;21 (1):63-69.

84. Tudor-Locke C, Craig CL, Beets MW et al. How many steps/day are enough? for children and adolescents. *Int J Behav Nutr Phys Act*. 2011;8 78.

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

86. Craig CL, Cameron C, Griffiths JM, Tudor-Locke C. Descriptive epidemiology of youth pedometer-determined physical activity: CANPLAY. *Med Sci Sports Exerc*. 2010;42 (9):1639-1643.

87. Craig CL, Cameron C, Tudor-Locke C. CANPLAY pedometer normative reference data for 21,271 children and 12,956 adolescents. *Med Sci Sports Exerc*. 2013;45 (1):123-129.

88. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep*. 1985;100 (2):126-131.

89. Wareham NJ, Rennie KL. The assessment of physical activity in individuals and populations: why try to be more precise about how physical activity is assessed? *Int J Obes Relat Metab Disord*. 1998;22 Suppl 2 S30-S38.

90. Westerterp KR. Assessment of physical activity: a critical appraisal. *Eur J Appl Physiol*. 2009;105 (6):823-828.

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

92. Sallis JF, Buono MJ, Freedson PS. Bias in estimating caloric expenditure from physical activity in children. Implications for epidemiological studies. *Sports Med*. 1991;11 (4):203-209.

93. Sallis JF. Self-report measures of children's physical activity. *J Sch Health*. 1991;61 (5):215-219.

94. Eston RG, Rowlands AV, Ingledew DK. Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children's activities. *J Appl Physiol*. 1998;84 (1):362-371.

95. Melanson ELJ, Freedson PS. Physical activity assessment: a review of methods. *Crit Rev Food Sci Nutr*. 1996;36 (5):385-396.

96. Emons HJ, Groenenboom DC, Westerterp KR, Saris WH. Comparison of heart rate monitoring combined with indirect calorimetry and the doubly labelled water (2H2(18)O) method for the measurement of energy expenditure in children. *Eur J Appl Physiol Occup Physiol*. 1992;65 (2):99-103.

97. Corder K, Ekelund U, Steele RM, Wareham NJ, Brage S. Assessment of physical activity in youth. *J Appl Physiol*. 2008;105 (3):977-987.

98. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity: convergent validity. *Sports Med*. 2002;32 (12):795-808.

99. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity: construct validity. *Sports Med*. 2004;34 (5):281-291.

100. Troiano RP. Translating accelerometer counts into energy expenditure: advancing the quest. *J Appl Physiol*. 2006;100 (4):1107-1108.

101. Karabulut M, Crouter SE, Bassett DRJ. Comparison of two waist-mounted and two ankle-mounted electronic pedometers. *Eur J Appl Physiol*. 2005;95 (4):335-343.

102. Crouter SE, Schneider PL, Karabulut M, Bassett DRJ. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc*. 2003;35 (8):1455-1460.

103. Rothman KJ, Greenland S, Professor TLLA. *Modern Epidemiology*. ThirdLippincott Williams & Wilkins; 2008.

104. Rowe DA, Mahar MT, Raedeke TD, Lore J. Measuring physical activity in children with pedometers: Reliability, reactivity, and replacement of missing data. *Pediatr Exerc Sci*. 2004;16 (4):343-354.

105. Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-determined steps per day in US children and youth. *Med Sci Sports Exerc*. 2010;42 (12):2244-2250.

106. Penpraze V, Reilly JJ, MacLean CM, Montgomery C, Kelly LA. Monitoring of physical activity in young children: how much is enough? *Pediatr Exerc Sci*. 2006;18 (4):483-491.

107. Vincent SD, Pangrazi RP. Does reactivity exist in children when measuring activity levels with pedometers?/La reactivite existe-t-elle chez des enfants lorsque que l\’on mesure leur niveau d\’activite al\’aide d\’un podometre? *Pediatr Exerc Sci*. 2002;14 (1):56-63.

108. De Meester F, De Bourdeaudhuij I, Deforche B, Ottevaere C, Cardon G.

Measuring physical activity using accelerometry in 13-15-year-old adolescents: the importance of including non-wear activities. *Public Health Nutr*. 2011;14 (12):2124-2133.

109. Ottevaere C, Huybrechts I, De Meester F, De Bourdeaudhuij I, Cuenca-Garcia M, De Henauw S. The use of accelerometry in adolescents and its implementation with non-wear time activity diaries in free-living conditions. *J Sports Sci*. 2011;29 (1):103-113.

110. Sirard JR, Melanson EL, Li L, Freedson PS. Field evaluation of the Computer Science and Applications, Inc. physical activity monitor. *Med Sci Sports Exerc*. 2000;32 (3):695-700.

111. Alberga AS, Sigal RJ, Goldfield G, Prud'homme D, Kenny GP. Overweight and obese teenagers: why is adolescence a critical period? *Pediatr Obes*. 2012;7 (4):261-273.

112. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet*. 2012;380 (9838):258-271.

113. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc*. 2000;32 (5):963-975.

114. Uijtdewilligen L, Nauta J, Singh AS et al. Determinants of physical activity and sedentary behaviour in young people: a review and quality synthesis of prospective studies. *Br J Sports Med*. 2011;45 (11):896-905.

115. Van Der Horst K, Paw MJ, Twisk JW, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth. *Med Sci Sports Exerc*. 2007;39 (8):1241-1250.

116. Seabra AF, Mendonca DM, Thomis MA, Anjos LA, Maia JA. [Biological and socio-cultural determinants of physical activity in adolescents]. *Cad Saude Publica*. 2008;24 (4):721-736.

117. Trost SG, Pate RR, Ward DS, Saunders R, Riner W. Determinants of physical activity in active and low-active, sixth grade African-American youth. *J Sch Health*. 1999;69 (1):29-34.

118. Trost SG, Loprinzi PD. Parental influences on physical activity behavior in children and adolescents: A brief review. *Am J Lifestyle Med*. 2011;5 (2):171-181.

119. Pugliese J, Tinsley B. Parental socialization of child and adolescent physical activity: a meta-analysis. *J Fam Psychol*. 2007;21 (3):331-343.

120. Duncan MJ, Al-Nakeeb Y, Woodfield L, Lyons M. Pedometer determined physical activity levels in primary school children from central England. *Prev*

Med. 2007;44 (5):416-420.

121. McGall SE, McGuigan MR, Nottle C. Contribution of free play towards physical activity guidelines for New Zealand primary school children aged 7-9 years. *Br J Sports Med*. 2011;45 (2):120-124.

122. Nyberg GA, Nordenfelt AM, Ekelund U, Marcus C. Physical activity patterns measured by accelerometry in 6- to 10-yr-old children. *Med Sci Sports Exerc*. 2009;41 (10):1842-1848.

123. Rowlands AV, Pilgrim EL, Eston RG. Patterns of habitual activity across weekdays and weekend days in 9-11-year-old children. *Prev Med*. 2008;46 (4):317-324.

124. Belton S, Brady P, Meegan S, Woods C. Pedometer step count and BMI of Irish primary school children aged 6-9 years. *Prev Med*. 2010;50 (4):189-192.

125. Cox M, Schofield G, Greasley N, Kolt GS. Pedometer steps in primary school-aged children: a comparison of school-based and out-of-school activity. *J Sci Med Sport*. 2006;9 (1-2):91-97.

126. Hardman CA, Horne PJ, Rowlands A. Children's pedometer-determined physical activity during school-time and leisure-time. *J Exerc Sci Fit*. 2009;7 (2):129-134.

127. Tudor-Locke C, McClain JJ, Hart TL, Sisson SB, Washington TL. Expected values for pedometer-determined physical activity in youth. *Res Q Exerc Sport*. 2009;80 (2):164-174.

128. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth a review. *Am J Prev Med*. 2011;41 (4):442-455.

129. Loprinzi PD, Cardinal BJ, Loprinzi KL, Lee H. Benefits and environmental determinants of physical activity in children and adolescents. *Obes Facts*. 2012;5 (4):597-610.

130. Molnar BE, Gortmaker SL, Bull FC, Buka SL. Unsafe to play? Neighborhood disorder and lack of safety predict reduced physical activity among urban children and adolescents. *Am J Health Promot*. 2004;18 (5):378-386.

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

132. Beets MW, Cardinal BJ, Alderman BL. Parental social support and the physical activity-related behaviors of youth: a review. *Health Educ Behav*. 2010;37 (5):621-644.

133. Gustafson SL, Rhodes RE. Parental correlates of physical activity in children and early adolescents. *Sports Med*. 2006;36 (1):79-97.

134. Heath GW, Parra DC, Sarmiento OL et al. Evidence-based intervention in physical activity: lessons from around the world. *Lancet*. 2012;380 (9838):272-281.

135. Kriemler S, Meyer U, Martin E, van Sluijs EM, Andersen LB, Martin BW. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *Br J Sports Med*. 2011;45 (11):923-930.

136. Salmon J, Booth ML, Phongsavan P, Murphy N, Timperio A. Promoting physical activity participation among children and adolescents. *Epidemiol Rev*. 2007;29 144-159.

137. Lytle LA, Seifert S, Greenstein J, McGovern P. How do children's eating patterns and food choices change over time? Results from a cohort study. *Am J Health Promot*. 2000;14 (4):222-228.

138. Veugelers PJ, Schwartz ME. Comprehensive school health in Canada. *Can J Public Health*. 2010;101 Suppl 2 S5-S8.

139. Carson V, Kuhle S, Spence JC, Veugelers PJ. Parents' perception of neighbourhood environment as a determinant of screen time, physical activity and active transport. *Can J Public Health*. 2010;101 (2):124-127.

140. Davidson Z, Simen-Kapeu A, Veugelers PJ. Neighborhood determinants of self-efficacy, physical activity, and body weights among Canadian children. *Health Place*. 2010;16 (3):567-572.

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

142. Organization WH, Dietz WH. Ottawa charter for health promotion. *Can J Public Health*. 1986;77 (6):425-430.

143. Veugelers PJ, Fitzgerald AL. Effectiveness of school programs in preventing childhood obesity: a multilevel comparison. *Am J Public Health*. 2005;95 (3):432-435.

144. Naylor PJ, Macdonald HM, Warburton DE, Reed KE, McKay HA. An active school model to promote physical activity in elementary schools: action schools! BC. *Br J Sports Med*. 2008;42 (5):338-343.

145. Luepker RV, Perry CL, McKinlay SM et al. Outcomes of a field trial to improve children's dietary patterns and physical activity. The Child and Adolescent Trial for Cardiovascular Health. CATCH collaborative group.

JAMA. 1996;275 (10):768-776.

146. Webber LS, Catellier DJ, Lytle LA et al. Promoting physical activity in middle school girls: Trial of Activity for Adolescent Girls. *Am J Prev Med*. 2008;34 (3):173-184.

147. Fung C, Kuhle S, Lu C et al. From "best practice" to "next practice": the effectiveness of school-based health promotion in improving healthy eating and physical activity and preventing childhood obesity. *Int J Behav Nutr Phys Act*. 2012;9 27.

148. Comte M, Hobin E, Majumdar SR, Plotnikoff RC, Ball GD, McGavock J. Patterns of weekday and weekend physical activity in youth in 2 Canadian provinces. *Appl Physiol Nutr Metab*. 2013;38 (2):115-119.

149. Corder K, van Sluijs EM, Ekelund U, Jones AP, Griffin SJ. Changes in children's physical activity over 12 months: longitudinal results from the SPEEDY study. *Pediatrics*. 2010;126 (4):e926-e935.

150. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. *JAMA*. 2008;300 (3):295-305.

151. Frohlich KL, Potvin L. Transcending the known in public health practice: the inequality paradox: the population approach and vulnerable populations. *Am J Public Health*. 2008;98 (2):216-221.

152. Breslin G, Brennan D, Rafferty R, Gallagher AM, Hanna D. The effect of a healthy lifestyle programme on 8-9 year olds from social disadvantage. *Arch Dis Child*. 2012;97 (7):618-624.

153. Caballero B, Clay T, Davis SM et al. Pathways: a school-based, randomized controlled trial for the prevention of obesity in American Indian schoolchildren. *Am J Clin Nutr*. 2003;78 (5):1030-1038.

154. Heath EM, Coleman KJ. Evaluation of the institutionalization of the coordinated approach to child health (CATCH) in a U.S./Mexico border community. *Health Educ Behav*. 2002;29 (4):444-460.

155. Jago R, McMurray RG, Drews KL et al. HEALTHY intervention: fitness, physical activity, and metabolic syndrome results. *Med Sci Sports Exerc*. 2011;43 (8):1513-1522.

156. Jurg ME, Kremers SP, Candel MJ, Van der Wal MF, De Meij JS. A controlled trial of a school-based environmental intervention to improve physical activity in Dutch children: JUMP-in, kids in motion. *Health Promot Int*. 2006;21 (4):320-330.

157. Lubans DR, Morgan PJ, Dewar D et al. The Nutrition and Enjoyable Activity

for Teen Girls (NEAT girls) randomized controlled trial for adolescent girls from disadvantaged secondary schools: rationale, study protocol, and baseline results. *BMC Public Health*. 2010;10 652.

158. Pate RR, Ward DS, Saunders RP, Felton G, Dishman RK, Dowda M. Promotion of physical activity among high-school girls: a randomized controlled trial. *Am J Public Health*. 2005;95 (9):1582-1587.

159. Robbins LB, Pfeiffer KA, Vermeesch A et al. “Girls on the Move” intervention protocol for increasing physical activity among low-active underserved urban girls: a group randomized trial. *BMC Public Health*. 2013;13 474.

2 Incorporating activity diaries into assessment of physical activity using pedometers among school-aged children

Vander Ploeg KA, Maximova K, Wu B, Veugelers PJ. Incorporating activity diaries into assessment of physical activity using pedometers among school-aged children. Under review in the *Journal of Sports Sciences* June 10, 2013.

2.1 Introduction

Regular physical activity is important for children's health. Among school-aged children, physical activity is protective against overweight and obesity, which is an established risk factor for chronic diseases including cardiovascular disease and diabetes.[1] To obtain health benefits, physical activity guidelines recommend that children and youth participate in 60 minutes of moderate-to-vigorous physical activity (MVPA) every day.[1-3] Accordingly, an accurate measurement of physical activity is important to identify children who are most at risk of disease, and to monitor progress of interventions and changes in physical activity and overtime.[4]

Activity monitors (i.e., accelerometers and pedometers) are commonly used to measure physical activity in epidemiologic studies of children and adolescents. These devices are small, unobtrusive, transportable, and require less time and financial and human resources to use compared with criterion measures such as doubly labeled water.[5] Several reviews have established accelerometers and pedometers as valid and reliable measures for assessing children's physical activity levels.[6-9] Activity monitors are more expensive and logistically challenging to use on a population level than self-report measures. However, activity monitors are generally recommended over self-reported physical activity measures because children's cognitive capacity and spontaneous and sporadic physical activity behaviours,[10] especially at a young age, may make it particularly challenging to accurately recall, categorize and record activities.[11]

Both accelerometers and pedometers are limited to the measurement of ambulatory activities i.e., walking, running. Consequently, they do not accurately capture activity gained through non-ambulatory activities including biking, skating, and skiing. There are also activities where safety regulations or discomfort restrict activity monitors from being worn e.g., soccer, martial arts, gymnastics. Furthermore, most accelerometers and pedometers are not waterproof, and therefore cannot be worn during water-based activities like swimming. This "non-wear time" may lead researchers to significantly underestimate actual physical activity levels, which leads to underestimating the proportion of study participants meeting physical activity recommendations, and herewith biased estimates of the proportion at risk for chronic diseases.[12-15]

Previous studies demonstrate that "non-wear time" biases are particularly relevant to the assessment of physical activity among children and youth.[12] Yet, there is a lack of consensus on a "best practice" approach to deal with energy expended during periods when activity monitors are not or cannot be worn. While it is common practice to keep activity diaries,[16-23] they are rarely used to supplement raw (crude) estimates derived from accelerometers and pedometers, whereas this may provide better understanding of relationship between physical activity and body weight. Furthermore, it may increase the ability to correctly identify children who are at risk of excess body weight and consequent chronic diseases. In this study, we compared the ability of four physical activity measures (i.e., self-report, crude steps from pedometers, crude steps adjusted for non-ambulatory activities and "non-wear time", and crude steps adjusted for missing data and non-ambulatory activities and "non-wear time") to identify school-aged children at risk of overweight and obesity.

2.2 Methods

2.2.1 Study design and population

Raising healthy Eating and Active Living (REAL) Kids Alberta is a population-based study of grade 5 students and parents in Alberta, Canada. In 2008, 148 randomly selected schools from across the Canadian Province of Alberta participated in the REAL Kids Alberta survey. The sampling-frame used to select schools has been described in detail elsewhere.[24] In the spring of 2009, we invited grade 5 students from 20 of the 148 schools to participate in an additional wave of data collection that included time-stamped pedometers. We also invited grade 5 students from 10 schools participating in the Alberta Program Promoting active Living and healthy Eating (APPLE) Schools.[25] We repeated data collection among grade 5 students from these 30 schools in the spring of 2011. The schools sampled in 2009 and 2011 were located in the City of Edmonton and surrounding area. Over both years, 2,507 parent consent forms and surveys were sent home with students for their parent(s) to complete and return to school; 2,045 (82%) home surveys were returned, of which 2,028 (99%) students received parental consent to participate. From those with parental consent, 1,991 (98%) students assented to participate and 1,977 (99%) children completed the student surveys. The overall participation rate was 79%. The Health Research Ethics Board of the University of Alberta approved this study, including data collection and parental informed consent forms.

2.2.2 Assessment of physical activity

Trained evaluation assistants traveled to schools to administer the Physical Activity Questionnaire for older Children (PAQ-C) to grade 5 students. The PAQ-C is a validated 7-day recall instrument that provides a summary score for general physical activity for children, aged 8 to 14 years.[26, 27] The summary score is calculated by taking the mean score of 9 items, each scored on a 5-point scale. The PAQ-C is a valid and reliable self-report measure for children's physical activity during the school year.[26, 27]

Physical activity was also measured objectively using Omron HJ-720ITC (Ontario, Canada) pedometers over a period of 9 days to capture 7 full days. The reasons for selecting this pedometer are described in detail elsewhere.[28] The accuracy and validity of the Omron pedometer has been demonstrated under various conditions.[29-32] Students wore pedometers for 9 consecutive days on their right hip directly in line with their right knee during all waking hours unless showering, swimming, or participating in activities in which an adult deemed it unsafe to wear. Students also kept a diary of their daily activities, including the duration of each activity and whether or not the pedometer was worn (available at: www.REALKidsAlberta.ca). On the ninth day, evaluation assistants returned to schools to collect pedometers.

2.2.3 Assessment of body weight status

Evaluation assistants measured student's standing height to the nearest 0.1 cm using stadiometers (Seca Stadiometer, Germany) and body weight to the nearest 0.1 kg on calibrated digital scales (Health-o-meter, model 320KL, IL, USA). Students removed their shoes for both measurements. Body mass index (BMI) was calculated as kg/m^2. A child was categorized as being overweight or obese based on the age- and sex-specific cutoff values of the International Obesity Task Force.[33]

2.2.4 Potential confounders

In the student survey, students reported their gender. In the home survey, the responding parent reported their highest level of education attained (no schooling, elementary, secondary, community/teaching college, university, graduate university) and the current annual household income from all sources (<$25,000, $25,000-50,000, $50,001-75,000, $75,001-100,000, >$100,000). The year of survey completion was also considered as a potential confounder.

2.2.5 Data processing and treatment

Due to differing administration and collection times, pedometer recordings from the first and last day (day 9) were not included in analyses. We defined a complete day as 8 or more hours of wear. We required such 'complete day' recordings on two school days and of one weekend day (weekend and/or holiday) as a minimum criterion to be considered in the present study. A total of 1,391 students met this criterion. We complimented students' crude steps with non-ambulatory and non-wear time activity step equivalents, which we refer to as "all activity steps". These steps were estimated from metabolically equivalent activities recorded in students' activity diaries, as described in detail elsewhere.[28] Missing data may occur if students forget to wear their pedometer and complete their activity diary for at least one hour. Missing data for specific hours of the day was imputed using information from the same hour at different, randomly selected, days of that individual (referred to as "complete steps"), as described in detail elsewhere.[28]

2.2.6 Statistical analysis

First, to assess construct validity, the association of each physical activity measure (PAQ-C, crude steps, all activity steps, and complete steps) with student's weight status was estimated in logistic regression models. Each physical activity measure was added sequentially to a base model that adjusted for student's gender, household income, parental educational attainment, and year of survey completion. The nested data structure (i.e., the clustering of students' observations within schools) was taken into account through random effects modeling with random intercepts for the schools.[24, 28] To compare the associations of the physical activity measures with overweight/obesity across models, we standardized step counts and PAQ-C scores to a mean of 0 and a standard deviation of 1 and applied adjusted random effects logistic regression models. To allow for an easier interpretation of odds ratios, we divided all step count measures by 1,000. As such, the presented odds ratios quantify a risk associated with a change in 1000 steps.

The receiver operating characteristic (ROC) analysis is a useful tool for evaluating the performance of different measures, in our case physical activity measures, to discriminate subjects with and without an outcome of interest, in our case normal weight vs. overweight and obese.[34] The receiver operating characteristic curve (AUC) statistic, also called the *c* statistic or *c* index, represents the probability of correctly classifying children who are normal weight vs. overweight and obese based on a set of predictors, and ranges from 0.5 (no discrimination) to 1.0 (perfect discrimination).[35, 36] We estimated the AUC statistic from the above described multivariable adjusted logistic random effects regression models. These AUC statistics quantify the ability of physical activity measures to identify children at risk of overweight (including obese) and obesity. We compared the AUC statistics for 'crude steps', 'all activity steps', and 'complete steps' versus the AUC statistic for PAQ-C. We also compared the AUC statistics for 'all activity steps' and 'complete steps' versus the AUC statistic for 'crude steps'. All analyses were conducted using Stata Version 12.0 (College Station, TX, USA).

2.3 Results

Table 1 shows selected characteristics of 1,391 students for whom pedometer data were available. The number of steps/day varied considerably based on pedometer-measured physical activity with and without taking non-wear time activities into account. 'All activity steps' (11,821 steps per day) were 22.0% higher than 'crude steps' (9,690) and 'complete steps' (12,357) were 27.5% higher. Consequently, there were differences in the proportions of children attaining physical activity recommendations when averaged over a typical week (i.e. five school days and two non-school days) based on pedometer-measured physical activity with and without taking non-wear time activities into account (45.2%, 56.6% and 59.5%, respectively).

All four physical activity measures were associated with children's overweight (including obese) and obesity (Table 2). The adjusted odds ratios for both overweight and obesity were slightly lower for 'crude steps' than for 'complete steps' (Table 2).

Table 3 presents the AUC statistics for five pairs of adjusted logistic regression models for overweight and obesity. The PAQ-C had the lowest ability to identify children at risk of overweight or obesity. Although measures of 'crude steps', 'all activity steps', and 'complete steps' showed a superior ability to 'PAQ-C' to identify children at risk of overweight, the improvement was not statistically significant. In contrast, measures of 'crude steps', 'all activity steps', and 'complete steps' showed a statistically significant superior ability to 'PAQ-C' to identify children at risk of obesity (p=0.009, 0.041, and 0.030, respectively).

2.4 Discussion

This study demonstrates the importance of adjusting pedometer measured step counts for non-ambulatory and non-wear time activities among school-aged children. We found that maximizing the use of all information collected from activity diaries resulted in a substantial increase in the proportion of children meeting physical activity guidelines and improved the relationship with overweight and obesity. Relative to self-reported physical activity, we found that physical activity measures that incorporated information from activity diaries showed an improved ability to identify children who are overweight and obese.

We found that taking into account non-ambulatory activities, non-wear time, and missing observations led to a 27.5% increase in the mean number of steps/day and a 31.6% increase in the proportion of children who met physical activity recommendations. The proportion of children considered physically active (i.e., attaining the recommended 13,500 steps/day) based on crude step counts averaged over a typical week (i.e., including five school days and two non-school days) was higher in our study relative to percentages (27%) previously reported in the literature for Canadian children.[2] The Canadian percentage may be lower because children in their sample ranged from ages 6-19, while the averaged age in our sample was 10.7 years, and physical activity tends to decline with age.[37] Further, the proportion of children attaining at least 13,500 steps/day increased substantially once the pedometer-measured crude step counts were adjusted for non-ambulatory activities, non-wear time, and missing observations. The unadjusted pedometer measured step counts misclassified 31.6% of children as not meeting the 13,500 step/day Canadian physical activity recommendation. A similar study by Ottevaere et al.[14] observed that 13.2% and 27.4% of boys and girls in their sample of 12-18 year-olds were misclassified as not meeting a similar recommendation of 60 minutes per day of MVPA. These findings highlight the importance of incorporating information from activity diaries to achieving accurate measures of physical activity of youth.

We observed that relative to self-reported physical activity, the association of children's physical activity with obesity was better captured when pedometer-measured step counts incorporated non-wear time activity step equivalents estimated from the activity diaries. We found that incorporating this information did not significantly improve the ability to identify children at risk of overweight relative to crude steps. However, these measures improved the ability to identify children at risk for the more severe form of excess body weight, obesity. It is possible that obese children were less compliant to our instructions of how to wear the pedometer. We instructed children to wear the monitors at the hip, directly in line with the right knee[38] for a minimum of 8-10 hours per day to obtain accurate measures of physical activity.[39, 40] Activity monitors attach to pants at the waistband or to an elastic belt, reportedly, may be particularly uncomfortable for children with a larger waist circumference wearing them for extended periods of time.[23, 41-43] Consequently, obese children may be more likely than normal weight children to remove the pedometer prior to or just after meeting wear-time criteria (generally a minimum of 8-10 hours per day[39, 40]). In this study, we found that pedometer data from obese children were more likely to be excluded because wear-time criteria were not met (66.2% and 54.3% of non-obese and obese students, respectively, had complete pedometer and survey data ($p<0.001$)). While, the characteristics of study participants not meeting wear-time inclusion criteria are rarely reported,[44] Ottevaere et al.[14] reported that participants excluded from their study had significantly higher BMI z-scores than those included, which is consistent with our observation. These findings have important implications for estimating individual physical activity levels, and may introduce selection and/or misclassification biases. However, incorporating information from activity diaries regarding participation in non-ambulatory and non-wear time activities provides a solution to help overcome these concerns.

Strengths of our study include the large sample size, use of time-stamped pedometers, and adjustments made to raw pedometer recorded steps from activities described in activity diaries. We used metabolic intensity equivalent values specific to youth, as described in detail elsewhere.[28] While the present study demonstrates the importance of including data from activity diaries, this information is self-reported and therefore may be subject to social desirability and recall biases. Additionally, although selected from a population-based sample, the sample of students in this study is not representative of the Alberta population. Caution is warranted when generalizing the present results.

2.5 Conclusion

This study shows that consideration should be given to activities that are not captured by pedometers as including these non-ambulatory activities may substantially improve the ability to accurately assess children's physical activity levels, and to identify children who are obese. Accordingly, researchers should consider incorporating information already collected in children's activity diaries to adjust raw activity monitor outputs to improve the ability to accurate measure physical activity and identify obesity among children.

2.6 References

1. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7 40.
2. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep*. 2011;22 (1):15-23.
3. Tremblay MS, Kho ME, Tricco AC, Duggan M. Process description and evaluation of Canadian Physical Activity Guidelines development. *Int J Behav Nutr Phys Act*. 2010;7 42.
4. Wareham NJ, Rennie KL. The assessment of physical activity in individuals and populations: why try to be more precise about how physical activity is assessed? *Int J Obes Relat Metab Disord*. 1998;22 Suppl 2 S30-S38.
5. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. *Sports Med*. 2001;31 (6):439-454.
6. Corder K, Ekelund U, Steele RM, Wareham NJ, Brage S. Assessment of physical activity in youth. *J Appl Physiol*. 2008;105 (3):977-987.
7. Eston RG, Rowlands AV, Ingledew DK. Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children's activities. *J Appl Physiol*. 1998;84 (1):362-371.
8. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity: convergent validity. *Sports Med*. 2002;32 (12):795-808.
9. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity: construct validity. *Sports Med*. 2004;34 (5):281-291.
10. Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and tempo of children's physical activities: an observational study. *Med Sci Sports Exerc*. 1995;27 (7):1033-1041.
11. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. *Res Q Exerc Sport*. 2000;71 (2 Suppl):S1-14.
12. Colley R, Connor Gorber S, Tremblay MS. Quality control and data reduction procedures for accelerometry-derived measures of physical

activity. *Health Rep*. 2010;21 (1):63-69.

13. De Meester F, De Bourdeaudhuij I, Deforche B, Ottevaere C, Cardon G. Measuring physical activity using accelerometry in 13-15-year-old adolescents: the importance of including non-wear activities. *Public Health Nutr*. 2011;14 (12):2124-2133.

14. Ottevaere C, Huybrechts I, De Meester F, De Bourdeaudhuij I, Cuenca-Garcia M, De Henauw S. The use of accelerometry in adolescents and its implementation with non-wear time activity diaries in free-living conditions. *J Sports Sci*. 2011;29 (1):103-113.

15. Sirard JR, Melanson EL, Li L, Freedson PS. Field evaluation of the Computer Science and Applications, Inc. physical activity monitor. *Med Sci Sports Exerc*. 2000;32 (3):695-700.

16. Bruner MW, Chad KE, Beattie-Flath JA et al. Examination of physical activity in adolescents over the school year. *Pediatr Exerc Sci*. 2009;21 (4):421-435.

17. Gaya AR, Alves A, Aires L, Martins CL, Ribeiro JC, Mota J. Association between time spent in sedentary, moderate to vigorous physical activity, body mass index, cardiorespiratory fitness and blood pressure. *Ann Hum Biol*. 2009;36 (4):379-387.

18. Gorter JW, Noorduyn SG, Obeid J, Timmons BW. Accelerometry: a feasible method to quantify physical activity in ambulatory and nonambulatory adolescents with cerebral palsy. *Int J Pediatr*. 2012;2012 329284.

19. Jago R, Anderson CB, Baranowski T, Watson K. Adolescent patterns of physical activity differences by gender, day, and time of day. *Am J Prev Med*. 2005;28 (5):447-452.

20. McLure SA, Summerbell CD, Reilly JJ. Objectively measured habitual physical activity in a highly obesogenic environment. *Child Care Health Dev*. 2009;35 (3):369-375.

21. Miller R, Brown WJ, Tudor-Locke C. But what about swimming and cycling? How to count non-ambulatory activity when using pedometers to assess physical activity. *J Phys Act Health*. 2006;3 257-266.

22. Peeters G, van Gellecum Y, Ryde G, Farías NA, Brown WJ. Is the pain of activity log-books worth the gain in precision when distinguishing wear and non-wear time for tri-axial accelerometers? *J Sci Med Sport*. 2013

23. Robertson W, Stewart-Brown S, Wilcock E, Oldfield M, Thorogood M. Utility of accelerometers to measure physical activity in children attending an obesity treatment intervention. *J Obes*. 2011;2011 8.

24. Simen-Kapeu A, Veugelers PJ. Should public health interventions aimed at

reducing childhood overweight and obesity be gender-focused? *BMC Public Health*. 2010;10 340.

25. Schwartz M, Karunamuni ND, Veugelers PJ. Tailoring and implementing comprehensive school health: The Alberta Project Promoting active Living and healthy Eating in Schools. *Revue phénEPS/PHEnex Journal*. 2010;2 (1):1-15.

26. Crocker PR, Bailey DA, Faulkner RA, Kowalski KC, McGrath R. Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. *Med Sci Sports Exerc*. 1997;29 (10):1344-1349.

27. Kowalski KC, Crocker PRE, RA. F. Validation of the Physical Activity Questionnaire for Older Children. *Pediatr Exerc Sci*. 1997;9 174-186.

28. Vander Ploeg KA, Wu B, McGavock J, Veugelers PJ. Physical activity among Canadian children on school days and nonschool days. *J Phys Act Health*. 2012;9 (8):1138-1145.

29. Crouter SE, Schneider PL, Karabulut M, Bassett DRJ. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc*. 2003;35 (8):1455-1460.

30. Hasson R, Haller J, Pober D, Staudenmayer J, Freedson P. Validity of the Omron HJ-112 pedometer during treadmill walking. *Med Sci Sports Exerc*. 2009;41 (4):805.

31. Holbrook E, Barreira T, Kang M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci Sports Exerc*. 2009;41 (3):670.

32. Zhu W, Lee M. Invariance of wearing location of Omron-BI pedometers: a validation study. *J Phys Act Health*. 2010;7 (6):706.

33. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320 (7244):1240-1243.

34. Zou KH, O'Malley AJ, Mauri L. Receiver-operating characteristic analysis for evaluating diagnostic tests and predictive models. *Circulation*. 2007;115 (5):654-657.

35. Cook NR. Use and misuse of the receiver operating characteristic curve in risk prediction. *Circulation*. 2007;115 (7):928-935.

36. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*. 1982;143 (1):29-36.

37. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of

physical activity: why are some people physically active and others not? *Lancet*. 2012;380 (9838):258-271.

38. Graser SV, Pangrazi RP, Vincent WJ. Effects of placement, attachment, and weight classification on pedometer accuracy. *J Phys Act Health*. 2007;4 (4):359-369.

39. Corder K, Brage S, Ekelund U. Accelerometers and pedometers: methodology and clinical application. *Curr Opin Clin Nutr Metab Care*. 2007;10 (5):597-603.

40. Penpraze V, Reilly JJ, MacLean CM, Montgomery C, Kelly LA. Monitoring of physical activity in young children: how much is enough? *Pediatr Exerc Sci*. 2006;18 (4):483-491.

41. Audrey S, Bell S, Hughes R, Campbell R. Adolescent perspectives on wearing accelerometers to measure physical activity in population-based trials. *Eur J Public Health*. 2013;23 (3):475-480.

42. Crocker PRE, Holowachuk DR, Kowalski KC. Feasibility of using the Tritrac motion sensor over a 7-day trial with older children. *Pediatr Exerc Sci*. 2001;13 (1):70-81.

43. Tudor-Locke CE, Myers AM. Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. *Res Q Exerc Sport*. 2001;72 (1):1-12.

44. McNamara E, Hudson Z, Taylor SJ. Measuring activity levels of young people: the validity of pedometers. *Br Med Bull*. 2010;95 121-137.

2.7 Tables

Table 2.1 Selected characteristics of the 1,391 participating grade 5 students.

	Overall N=1391
	Mean (SD) or %
Mean age, yrs	10.9 (0.4)
Mean BMI, kg/m^2	19.56 (4.0)
Body weight status, %	
Overweight	20.0
Obese	10.6
Physical Activity	
PAQ-C, score	3.3 (0.8)
Crude steps, steps/day	9690 (2897)
All activity steps, steps/day	11,825 (3,849)
Complete steps, steps/day	12,357 (3909)
Meet PA recommendations, %*	
Steps crude	45.2
Steps all activities	56.6
Steps complete	59.5
Parental education attainment, %	
Secondary or less	26.0
College Diploma	42.3
University or graduate degree	31.7
Household income, %	
<$50,000	23.8
$50,001-$75,000	16.6
$75,001-$100,000	18.6
>$100,000	41.0

*≥13,500 steps/day

Table 2.2 Odds ratios (95% CI) of overweight and obesity by measures of physical activity

	Univariable Analysis			Multivariable Analysis*		
	Odds Ratio	95% CI	p-value	Odds Ratio	95% CI	p-value
Overweight						
PAQ-C	0.778	0.681-0.888	<0.001	0.752	0.657-0.860	<0.001
Crude steps	0.764	0.666-0.877	<0.001	0.727	0.630-0.840	<0.001
All activity steps	0.806	0.705-0.921	0.002	0.787	0.683-0.906	0.001
Complete steps	0.815	0.713-0.931	0.003	0.793	0.689-0.913	0.001
Obese						
PAQ-C	0.816	0.669-0.997	0.046	0.790	0.646-0.967	0.022
Crude steps	0.698	0.552-0.883	0.003	0.654	0.515-0.831	0.001
All activity steps	0.707	0.560-0.892	0.003	0.691	0.543-0.880	0.003
Complete steps	0.716	0.568-0.902	0.005	0.696	0.547-0.884	0.003

* Odd ratios and 95% confidence intervals were estimated through multilevel logistic regression models. Multivariate analyses adjusted for differences in gender, parental education attainment, household income, and year of data collection.

Table 2.3 Area under the ROC curve (AUC) (95% CI) coefficients from multilevel logistic regression models* for overweight and obesity (n=1,391).

Model		Overweight			Obesity		
		AUC	95% CI	p-value	AUC	95% CI	p-value
1	PAQ-C	0.597	0.561- 0.633	0.156	0.633	0.572 - 0.694	0.009
	Crude steps	0.621	0.585 - 0.657		0.689	0.635 - 0.742	
2	PAQ-C	0.597	0.561- 0.633	0.463	0.633	0.572 - 0.694	0.041
	All activity steps	0.609	0.572 - 0.645		0.675	0.619 - 0.732	
3	PAQ-C	0.597	0.561- 0.633	0.516	0.633	0.572 - 0.694	0.030
	Complete steps	0.607	0.571 - 0.644		0.677	0.620 - 0.733	
4	Crude steps	0.621	0.585 - 0.657	0.105	0.689	0.635 - 0.742	0.180
	All activity steps	0.609	0.572 - 0.645		0.675	0.619 - 0.732	
5	Crude steps	0.621	0.585 - 0.657	0.092	0.689	0.635 - 0.742	0.258
	Complete steps	0.607	0.571 - 0.644		0.677	0.620 - 0.733	

* Adjusted for gender, parental education attainment, household income, and year of data collection.

3 Physical activity among Canadian children on school days and non-school days

Vander Ploeg KA, Wu B, McGavock J, Veugelers PJ. Physical activity among Canadian children on school days and non-school days. *J Phys Act Health* 2012;9(8):1138-1145.

3.1 Introduction

Regular physical activity has beneficial effects on reducing obesity and improving health.[1-3] Despite these benefits, the majority of Canadian children do not meet the recommended[4] 60 minutes of moderate-to-vigorous physical activity or 13,500 steps daily.[1, 5, 6] Population-based studies show that 26%–29% of Canadian children and youth are overweight or obese.[7, 8] Because overweight in childhood often persists into adulthood, a rising number of children are at increased risk of obesity and consequent chronic disease.[9, 10] Increasing physical activity levels among children is therefore a public health priority.

Schools provide children multiple opportunities for physical activity throughout the day. As children spend substantial time at schools, they are considered an ideal environment to implement interventions to increase physical activity. Although schools provide guaranteed opportunities for physical activity through physical education and recess, its remains unclear if the majority of children's physical activity is achieved during school hours. While some studies have noted significantly higher levels of physical activity after school hours,[11-14] others have not.[15-17] Discrepancies between studies can be explained by several factors, including study design, duration of observation, climate, and method used to assess physical activity. Several of these limitations can be overcome by recording hourly records of physical activity on both weekdays and weekends in robust samples of children during seasons in which weather is less of a barrier to physical activity participation.

The purpose of our study was to resolve previous studies by assessing physical activity objectively using time-stamped pedometers over the course of a typical week with measurements in a population-based sample of youth during the spring months of the school year. We hypothesized that physical activity would be lowest during the windows of time that students were at school.

3.2 Methods

3.2.1 Study design

The Raising healthy Eating and Active Living (REAL) Kids Alberta is a population-based study of grade 5 students age 10–11 in Alberta, their parents, and their school principals.[8] In 2008, the REAL Kids Alberta survey included 148 randomly selected schools from across the Canadian Province of Alberta. In 2009, we selected and invited 20 of these 148 schools, located in the city of Edmonton and surrounding areas, to participate in an additional survey. In addition, we invited grade 5 students from 10 schools participating in the Alberta Program Promoting active Living and healthy Eating Schools (APPLE Schools).[18] In this survey, we objectively measured hourly step counts using time-stamped pedometers.

Details of the projects and survey tools are accessible through www.realkidsalberta.ca and www. APPLESchools.ca. The current study, including data collection and parental informed consent forms, was approved by the Human Research Ethics Board at the University of Alberta.

3.2.2 Participants

We invited 1,271 parents of grade 5 students to provide their informed consent for their children to participate in this survey. A total of 984 (77%) requests were returned, with 975 (99%) granting consent. Of the students whose parents provided consent, 973 (99%) students assented to participate (Figure 1).

3.2.3 Outcome variable: physical activity

We used Omron HJ-720ITC (Ontario, Canada) pedometers to measure physical activity objectively in the form of hourly step counts recorded over a period of 7 days. Hourly step counts allows for more precise evaluation of patterns of physical activity throughout the day. The Omron pedometer also features a 41-day storable memory and is automatically reset at midnight; thereby eliminating the need for participants to record their step counts at the end of each day. In addition to recording steps, this pedometer has a sensitive motion detector, which indicates through a binary variable whether it was worn. This feature allowed us to distinguish periods of sedentary behavior from non-wear time providing a more objective record of student compliance with wearing the pedometer. The accuracy and validity of the Omron pedometer has been demonstrated under various conditions.[19-21]

We instructed students to wear the pedometers for 9 consecutive days. We chose not to include records from the first and last day in our analysis due to differing administration and collection times, along with any potential reactivity to wearing the pedometers.[22] We asked children to wear the pedometer during all waking hours unless showering, swimming, or taking part in activities in which an adult deemed unsafe to wear. We directed students to wear the pedometer on their right hip directly in line with their right knee. Students were also asked to keep a log of their daily activities including the duration and whether the pedometer was worn in an activity log (available at www.realkidsalberta.ca).

The evaluation assistants returned to schools on the third day of data collection to encourage students to wear the pedometers and to complete their activity logs. On the ninth day, research staff returned to the schools to collect pedometers and download the data to computers. Nine hundred and twenty-three (95%) pedometers were returned, providing crude hourly step counts; 50 (5%) pedometers were lost or malfunctioned.

We considered a pedometer recording to be complete when a pedometer was worn for a minimum of 8 consecutive hours per day.[23] To be included in our analysis we required students to provide valid pedometer recordings on at least 2 school days and 1 non-school day (weekend and/or holiday).[24] Based on these criteria, we included 689 (75%) students in our analysis (Figure 1).

3.2.4 Confounding variables

Evaluation assistants measured standing height to the nearest 0.1 cm using stadiometers (Seca Stadiometer, Germany) and body weight to the nearest 0.1 kg on calibrated digital scales (Health o meter, model 320KL, IL, USA). Students removed their shoes for both measurements. With parent consent and student ascent, evaluation assistants visited the participating schools to administer a background survey on lifestyle behavior.

3.2.5 Data processing

Although pedometers measure ambulatory activity, they do not accurately capture energy expenditure from activities such as biking, skating, and skiing. Because Canadian children and youth report similar participation rates between both ambulatory activities and non-ambulatory activities,[25] relying on crude step counts may underestimate their actual activity level. To overcome this, we complemented crude step counts with step counts estimated from activities recorded by students in their daily activity logs (referred to as 'log-adjusted steps'). To adjust crude step counts first, we assigned each activity a youth-specific metabolic equivalent task (MET) unit.[26] When youth specific values were not available we used adult MET units.[27] Next, we categorized activities into moderate (0–3 MET), moderate to vigorous (3.1–5.9 MET), and vigorous (6.0–8.9 MET) intensities[27, 28] and assigned a step per minute value to each category.[29] Finally, we were able to estimate step counts for each activity a student described by multiplying the step-per-minute value for each respective category by two-thirds of the duration of the activity recorded in their activity log as per the NASPE[30] guideline that 15 minutes of children's activity is made up of 10 minutes of activity interspersed with 5 minutes of rest. This procedure was used to estimate the steps that would have been achieved during activities in which students could not wear their pedometer (i.e., swimming). When students forgot to wear their pedometer and complete their activity log, we imputed information from other randomly selected valid days. For example, if a student forgot to wear his/her pedometer between 7:00 PM and 8:00 PM on a school day, their pedometer or log-adjusted steps during this period on another randomly selected school day were imputed to this missing hour. When possible, we imputed steps for all missing hours of complete days. We imputed steps only within an individual, within school days between 7:00 AM and 9:00 PM, and within non-school days between 9:00 AM and 9:00 PM. Differing patterns of behavior observed from weekdays to weekend days dictated the time periods for imputation.

We considered activities gained through travel to and from school as activities during 'school hours' because these activities are characteristic of behaviors on school days.

3.2.6 Statistical analyses

Body mass index (BMI) was calculated as kg/m2. Overweight and obesity were defined using the International Obesity Task Force BMI cut-off points established for children and youth.[31] These cut-off points are based on health-related adult definitions of overweight (BMI ≥ 25) and obesity (BMI ≥ 30), but are adjusted to specific age and sex categories for children[31] Descriptive statistics are presented as means ± SD or frequencies. We used independent *t*-tests to analyze sex-specific differences on school days, on non-school days, and during a typical week of 5 school days and 2 non-school days. We used paired *t*-tests stratified by sex to analyze differences in total steps per day on school days and non-school days and differences in total steps per hour during school hours and non-school hours. We considered the proportion of boys and girls who achieved 13,500 steps per day to have met the Canadian recommendation for physical activity. To analyze sex differences in the proportion of boys and girls who met the Canadian recommendation of 13,500 steps per day we used Chi-square (χ^2) tests.

3.3 Results

Six hundred and eighty-nine students (318 boys and 371 girls) wore a pedometer for a minimum of 8 consecutive hours on at least 2 school days and 1 weekend day. Descriptive statistics are reported in Table 1. There were no sex-based differences in age, BMI, or weight status (normal weight, overweight, or obese).

The average crude daily step count for a typical week in the entire cohort was 9,221 ± 3,027 steps per day. However, when information provided through the activity logs was considered the average daily step count increased to 11,189 ± 3561 steps per day, a mean difference of 1,968 steps per day ($P < 0.001$). Lastly, with imputations for the time that students forgot to or could not wear their pedometers we observed an average daily step count of 11,871 ± 3,680 steps per day, a mean difference of 682 steps per day from the activity log adjusted step count (P < 0.001). Figure 2 shows how the adjustments affect step counts by activity level.

Table 2 depicts activity during various windows of time for boys and girls. Boys achieved significantly more steps per day than girls on school days (+ 2,040 steps/day, $P < 0.001$), on non-school days (+ 753 steps/day, $P = 0.03$), and during a typical week (+ 1,672 steps/day, $P < 0.001$). What is more, during school hours as well as outside of school hours, boys took significantly more steps per hour than girls during the school day (+ 141 steps/hour, $P < 0.001$; + 145 steps/hour, $P < 0.001$), respectively.

Table 2 also shows that the daily step-count was significantly higher during school days compared with non-school days (boys + 2,467 ± 5,262 steps/day, $P < 0.001$; girls + 1,180 ± 4,459 steps/day, $P < 0.001$). In addition, both boys and girls took significantly more steps per hour during school hours than during before and after school hours (boys + 206 ± 420, $P < 0.001$; girls +210 ±347, $P < 0.001$). The differences between weekday and weekend physical activity are further illustrated in Figure 3. Figure 3 shows that the differences in activity levels between school days and non-school days occurred primarily during the following windows: the 8:00–9:00 AM, 10:00–11:00 AM, 12:00–1:00 PM, and 3:00–4:00 PM. These windows of time seem to coincide with travel to and from school, lunch hour, and recess times. Apart from these times, there is relatively little variation in steps achieved on school days and weekend days. However, the decline in activity from school days to weekends was more pronounced for boys (–2,467 steps/day) than for girls (–1,180 steps/day) (Table 2).

Calculation of the average step count on school days for each participant revealed that 43% of boys and 21% of girls met the recommendation of 13,500 daily steps or more ($P < 0.001$). For non-school days, this was 30% for boys and 22% for girls ($P = 0.01$). And for a typical week, this was 37% for boys and 19% for girls ($P < 0.001$). The proportion of students who achieved less than half of the recommended steps was higher on non-school days (23% of boys and 27% of girls) than on school days (3% of boys and 3% girls).

3.4 Discussion

Two novel findings emerged from this cross sectional study of physical activity patterns in grade 5 students, primarily 10–11 years of age. First, we found that physical activity outside of school hours and on weekend days is significantly lower than physical activity during school hours and on school days, particularly among boys. Second, excess physical activity comes primarily from a set number of hours.

The current study shows that 27% of the surveyed students are meeting the recommended 13,500 steps/day required for optimal growth and development. This proportion is slightly lower than the Canadian national rate of approximately 31% from 2007–2009.[4] The proportion of children who achieve 13,500 daily steps in Alberta is unknown due to recent changes in the Canadian recommendation for daily physical activity. However, Alberta and national percentages were close based on the old recommendation of 16,500 steps/day[32, 33] Over a typical 5-day school week, the daily average step count (11,871 ± 3680 steps/day) was slightly higher than the provincial (11,600 steps/day)[33] and national (boy 12,100 steps/day, girls 10,300 steps/day) averages.[4]

In support of previous literature,[4, 16, 34, 35] boys were found to be more active than girls with a mean step difference of 2040 steps per day ($P < 0.001$) during a typical week. There was, however, a greater decline in physical activity levels between weekdays and weekends for boys compared with girls. This is different from previous studies[13, 16] where girls were more susceptible to a drop in activity levels on weekend days. The school environment provides structured opportunity for children to engage in regular physical activity throughout the week (e.g., active transportation, active play before and after school, during recess, and lunch time, physical education classes). Health promotion strategies should target girls such that their physical activity benefits from these opportunities as it does for boys.

We observed children to be more active on school days relative to non-school days. This finding is consistent with some,[15, 16, 22, 36, 37] but not others.[11-13, 28] It is believed that the variability in physical activity between weekdays and week-ends relates to a number of factors that are not well understood (e.g., age, culture, involvement in sports).[17] Despite the observation that youth are more active on school days than weekend days, their daily step counts on weekdays remain below the current recommendation. This indicates that opportunities for physical activity provided at school alone are not sufficient for children to accumulate adequate physical activity to gain both current and future health benefits. Health promotion strategies should therefore extend to after school hours and weekends.

We also observed physical activity levels to be higher during school hours than non-school hours. Again, there is variability in the literature between activity levels during school hours and non-school hours; some studies report higher levels during school[36, 37] and others report higher levels outside of school.[11, 13, 22] The inconsistencies between results reported here and results in the literature may be attributed to the fact that Hardman et al.,[13] Betlon et al.,[11] and Cox et al.[12] recorded school time activities only during the time students were at school. We had considered active transport as physical activity related to the school routine. From Figure 3 it is evident that a large proportion of children's daily activity was gained during periods when children would be traveling to and from school.

Despite the observation that physical activity is higher during school hours, excess physical activity was primarily achieved during discretionary periods including recess, lunch breaks, and active transportation to and from school. It is widely known that while at school, children are seated for a large percentage of the day and opportunities for physical activity are limited to recess, lunch breaks, and physical education classes. Targeted interventions maximizing activity during these periods have been suggested to increase levels of physical activity.[38] Currently, only 38% of Alberta children report using active transport to and from school.[39] Activity levels, therefore, can be expected to increase substantially if all students would engage in active transport.

The increasingly widespread use of pedometers in both research and practice reinforces the importance of providing physical activity estimates truly reflective of the population. The current study showed that it is important to consider non-ambulatory activities that are not recorded well with pedometers, as these constitute a substantial proportion of all activities. We have included steps estimated from activities recorded in daily logs for those activities in which the pedometer could not be worn (e.g., swimming), for those in which the pedometer could not accurately measure (e.g., biking, gymnastics, and karate), and for those when students forgot to wear the pedometer. As a result, we are able to provide an average daily step count that more accurately reflects the actual physical activity behaviour of children. Adjusting for the above also allows us to maintain a larger sample from which estimates of daily activity are drawn. Accordingly, we provide an estimate of children's physical activity that is more representative of the population.

Estimates of daily physical activity using objective measures are affected by the number of hours per day pedometers are worn. When pedometers are removed for prolonged periods physical activity levels may be underestimated because the actual behavior is not captured. To overcome this potential bias, wear-time criterion has been established. Some pedometers studies eliminate data from participants who report removing their pedometer for more than 1 hour,[15, 40, 41] more than 2 hours,[13] or longer[11] during the monitored day. Others required that the pedometer be worn for a minimum of 10 hours for a monitored day to be included in the final analysis.[42] The application of the above criterion resulted in the exclusion of 5–11%,[18, 26] 24%,[17, 18, 26] and 37%[42] of participants, respectively. Penpraze et al.[23] showed that reliability increases as the number of days and hours of monitoring increased, but only to 10 hours per day. Penpraze et al.[23] also showed that reliability was more dependent on the number of days than the number of hours. In the current study, 8 hours was selected as the minimum daily wear criterion. By reducing the amount of time per day that students were expected to wear their pedometers we maintain a larger sample size and maintain estimates from less active children who under more conservative requirements may have otherwise been excluded. This is an important consideration when generating population-based estimates of physical activity.

Strengths of our study include the use of time-stamped pedometers. Another strength of our study is the adjustments made to raw pedometer recorded steps from activities described in daily activity logs, as this has not been recorded in the literature. This study shows that consideration should be given to activities that are not captured by pedometers, as ignoring these non-ambulatory activities may lead to a substantial underestimation of the actual activity level. We used MET values specific to youth when possible. However, when youth values were not available, we used adult values instead. Although selected from a population-based sample, the sample of students in this study is not representative of the Alberta population. Caution is warranted when generalizing the present results.

3.5 Conclusion

A significant portion of youth 10 to 11 years in the province of Alberta are not achieving current recommendations for physical activity, especially on weekend days. Children were significantly more active during school days and school-hours than compared with non-school days and after school hours. Physical activity interventions and policies should recognize these trends and consider strategies that target these windows of time.

3.6 References

1. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7 40.
2. Must A, Tybor DJ. Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth. *Int J Obes*. 2005;29 S84-S96.
3. Tremblay MS, Willms JD. Is the Canadian childhood obesity epidemic related to physical inactivity? *Int J Obes Relat Metab Disord*. 2003;27 (9):1100-1105.
4. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep*. 2011;22 (1):15-23.
5. Canadian Society for Exercise Physiology P. Canadian Society for Exercise Physiology and ParticipACTION share new research to inform Canadians of physical activity levels required.
6. Tremblay MS, Kho ME, Tricco AC, Duggan M. Process description and evaluation of Canadian Physical Activity Guidelines development. *Int J Behav Nutr Phys Act*. 2010;7 42.
7. Shields M. Overweight and obesity among children and youth. *Health Rep*. 2006;17 (3):27-42.
8. Simen-Kapeu A, Veugelers PJ. Should public health interventions aimed at reducing childhood overweight and obesity be gender-focused? *BMC Public Health*. 2010;10 340.
9. Dietz WH. Overweight in childhood and adolescence. *N Engl J Med*. 2004;350 (9):855-857.
10. Manson JE, Bassuk SS. Obesity in the United States: a fresh look at its high toll. *JAMA*. 2003;289 (2):229-230.
11. Belton S, Brady P, Meegan S, Woods C. Pedometer step count and BMI of Irish primary school children aged 6-9 years. *Prev Med*. 2010;50 (4):189-192.

12. Cox M, Schofield G, Greasley N, Kolt GS. Pedometer steps in primary school-aged children: a comparison of school-based and out-of-school activity. *J Sci Med Sport*. 2006;9 (1-2):91-97.

13. Hardman CA, Horne PJ, Rowlands AV. Children's pedometer-determined physical activity during school-time and leisure-time. *J Exerc Sci Fit*. 2009;7 (2):129-134.

14. Tudor-Locke C, Lee SM, Morgan CF, Beighle A, Pangrazi RP. Children's pedometer-determined physical activity during the segmented school day. *Med Sci Sports Exerc*. 2006;38 (10):1732-1738.

15. Duncan MJ, Al-Nakeeb Y, Woodfield L, Lyons M. Pedometer determined physical activity levels in primary school children from central England. *Prev Med*. 2007;44 (5):416-420.

16. Rowlands AV, Pilgrim EL, Eston RG. Patterns of habitual activity across weekdays and weekend days in 9-11-year-old children. *Prev Med*. 2008;46 (4):317-324.

17. Tudor-Locke C, McClain JJ, Hart TL, Sisson SB, Washington TL. Expected values for pedometer-determined physical activity in youth. *R Q Exerc Sport*. 2009;80 (2):164-174.

18. Schwartz M, Karunamuni ND, Veugelers PJ. Tailoring and implementing comprehensive school health: The Alberta Project Promoting active Living and healthy Eating in Schools. *Revue phénEPS/PHEnex Journal*. 2010;2 (1):1-15.

19. Hasson R, Haller J, Pober D, Staudenmayer J, Freedson P. Validity of the Omron HJ-112 pedometer during treadmill walking. *Med Sci Sports Exerc*. 2009;41 (4):805.

20. Holbrook E, Barreira T, Kang M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci Sports Exerc*. 2009;41 (3):670.

21. Zhu W, Lee M. Invariance of wearing location of Omron-BI pedometers: a validation study. *J Phys Act Health*. 2010;7 (6):706.

22. Rowe DA, Mahar MT, Raedeke TD, Lore J. Measuring physical activity in children with pedometers: Reliability, reactivity, and replacement of missing data. *Pediatr Exerc Sci*. 2004;16 (4):343-354.

23. Penpraze V, Reilly JJ, MacLean CM, Montgomery C, Kelly LA. Monitoring of

physical activity in young children: how much is enough? *Pediatr Exerc Sci*. 2006;18 (4):483-491.

24. Craig CL, Tudor-Locke C, Cragg S, Cameron C. Process and treatment of pedometer data collection for youth: the Canadian Physical Activity Levels among Youth study. *Med Sci Sports Exerc*. 2010;42 (3):430-435.

25. Institute CFLR, Armstrong TP, Xuereb GC. Bulletin 7: Children's participation in sport. 2010

26. Ridley K, Ainsworth BE, Olds TS. Development of a compendium of energy expenditures for youth. *Int J Behav Nut Phys Act*. 2008;5 (1):45.

27. Ainsworth BE, Haskell WL, Whitt MC et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32 (9;S1):S498-S504.

28. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc*. 2000;32 (2):426-431.

29. Jago R, Watson K, Baranowski T et al. Pedometer reliability, validity and daily activity targets among 10- to 15-year-old boys. *J Sports Sci*. 2006;24 (3):241-251.

30. (NASPE) NAfSaPE. Physical activity for children: a statement of guidelines for children ages 5-12. 2004

31. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320 (7244):1240-1243.

32. Institute ICFaLR. Bulletin 1: Activity levels of Canadian children and youth. 20091-6.

33. Institute ICFaLR. Bulletin 1.9: Physical activity levels of children and youth in Alberta. 20101-3.

34. Trost SG, Pate RR, Sallis JF et al. Age and gender differences in objectively measured physical activity in youth. *Med Sci Sports Exerc*. 2002;34 (2):350-355.

35. Vincent SD, Pangrazi RP. An examination of the activity patterns of elementary school children. *Pediatr Exerc Sci*. 2002;14 (4):432-441.

36. McGall SE, McGuigan MR, Nottle C. Contribution of free play towards

physical activity guidelines for New Zealand primary school children aged 7-9 years. *Br J Sports Med*. 2011;45 (2):120-124.

37. Nyberg GA, Nordenfelt AM, Ekelund U, Marcus C. Physical activity patterns measured by accelerometry in 6- to 10-yr-old children. *Med Sci Sports Exerc*. 2009;41 (10):1842-1848.

38. Beighle A, Morgan CF, Le Masurier G, Pangrazi RP. Children's physical activity during recess and outside of school. *J School Health*. 2006;76 (10):516-520.

39. Carson V, Kuhle S, Spence JC, Veugelers PJ. Parents' perception of neighbourhood environment as a determinant of screen time, physical activity and active transport. *Can J Public Health*. 2010;101 (2):124-127.

40. De Bourdeaudhuij I, Cardon G. A pilot study comparing pedometer counts with reported physical activity in elementary schoolchildren. *Pediatr Exerc Sci*. 2004;16 (4):355-367.

41. Tudor-Locke C, Pangrazi RP, Corbin CB et al. BMI-referenced standards for recommended pedometer-determined steps/day in children. *Prev Med*. 2004;38 (6):857-864.

42. Eisenmann JC, Laurson KR, Wickel EE, Gentile D, Walsh D. Utility of pedometer step recommendations for predicting overweight in children. *Int J Obes*. 2007;31 (7):1179-1182.

3.7 Tables

Table 3.1: Descriptive statistics of grade 5 student sample.

	Boys (n=318)	**Girls** (n=371)	**Total** (n=689)
Age (yr)	10.9 ± 0.4	10.9 ± 0.4	10.9 ± 0.4
BMI (kg/m^2)	19.7 ± 4.0	19.3 ± 3.5	19.5 ± 3.7
Normal weight	63% (199)	67% (250)	65% (449)
Overweight	25% (80)	22% (80)	23% (160)
Obese	10% (33)	8% (28)	9% (61)

Table 3.2: Average number of steps (± standard deviation) of 689 students on school days, during school hours, before and after school hours, on non-school days, during a typical week of 5 school days and 2 non-school days.

	Boys (n=318)	**Girls** (n=371)	**Total** (n=689)
School day (steps/day)	13,476 ± 4,123	11,436 ± 3,158**	12,377 ± 3,773
During school (steps/hour)	1,024 ±290	883 ± 226**	948 ± 267
Before & after school (steps/hour)	818 ± 419	673 ± 332**	740 ± 382
Non-school day (steps/day)	11,009 ± 5,542	10,256 ± 5,206*	10,604 ± 5,373
Typical week (steps/day)	12,771 ± 3,907	11,099 ± 3,288**	11,871 ± 3,680

** $p < 0.05$; ** $p < 0.001$

3.8 Figures

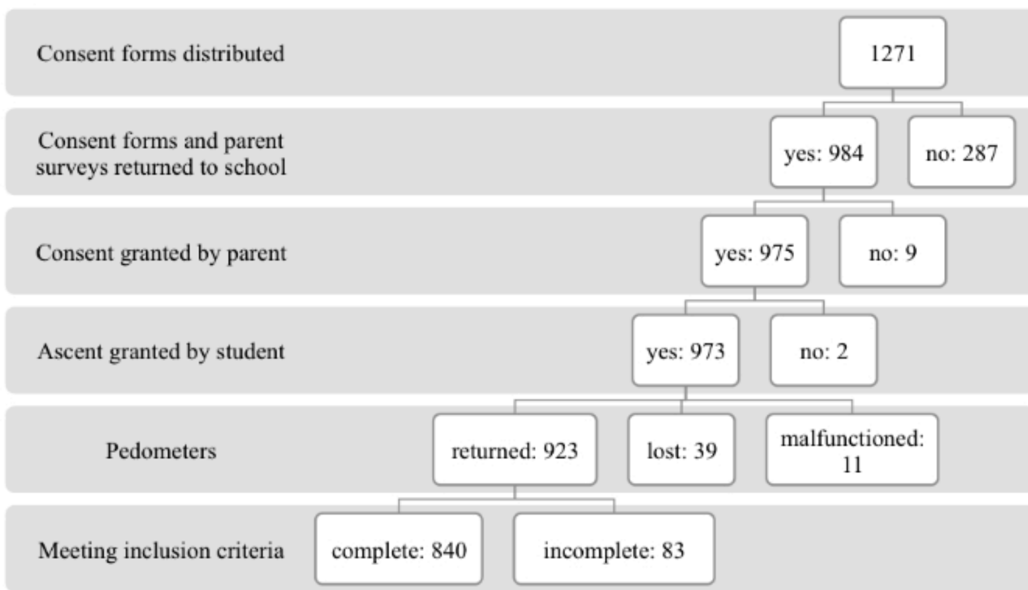

Figure 3.1: Description of enrollment of grade 5 students in the study and their pedometer usage.

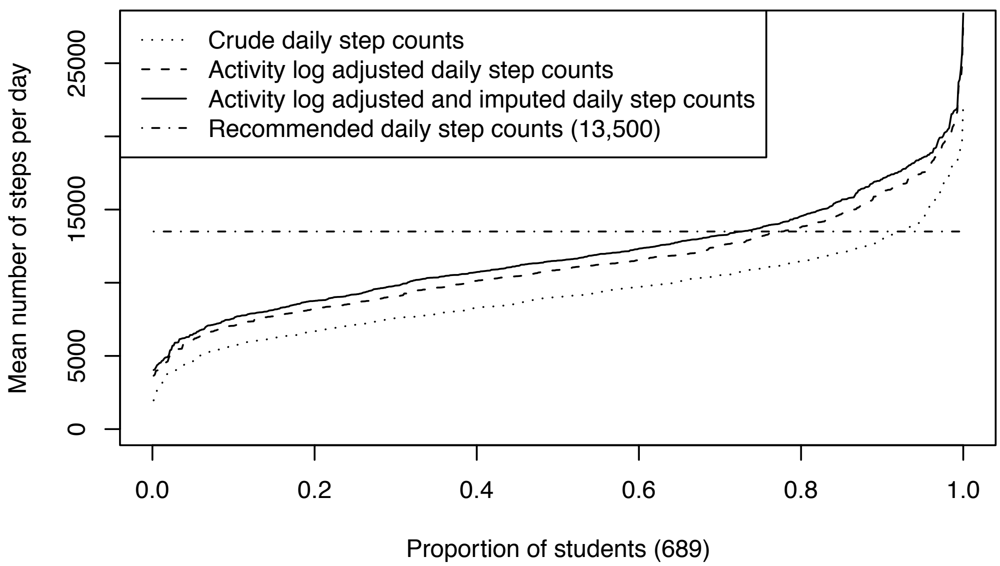

Figure 3.2: Mean number of daily steps among grade 5 students.

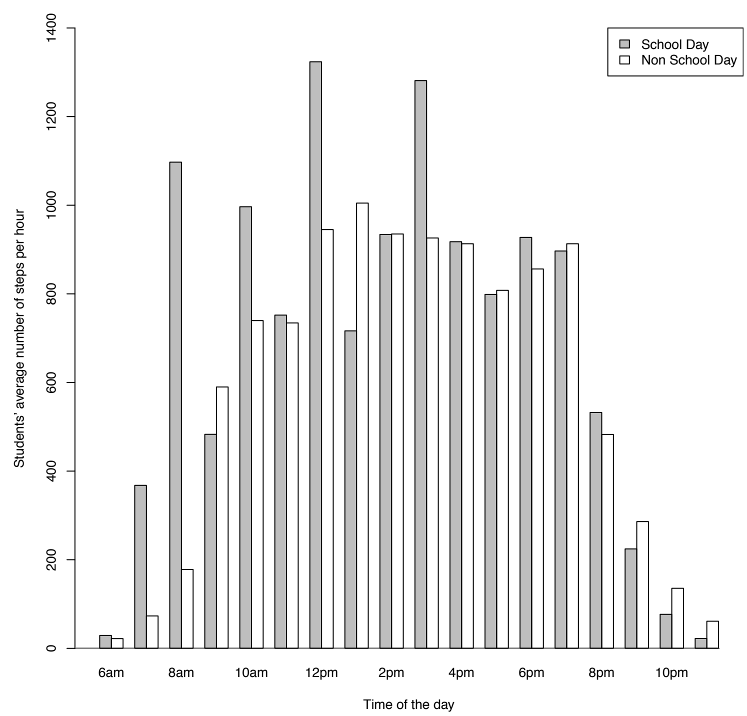

Figure 3.3: Average number of daily steps among 689 students from 30 schools in Alberta, Canada on school days and non-school days.

4 The importance of parental beliefs and support for physical activity and body weights of children: a population-based analysis

Vander Ploeg KA, Maximova K, Kuhle S, Simen-Kapeu A, Veugelers PJ. The importance of parental beliefs and support for physical activity and body weights of children: a population-based analysis. *Can J Public Health* 2012;103(4):277-281.

4.1 Introduction

Overweight and obesity in childhood are major public health concerns. They negatively impact self-esteem and academic performance.[1, 2] Because overweight children tend to become overweight adults, an increasing number of children will face chronic disease in their lifetime.[3, 4] In Canada, the prevalence of childhood overweight has more than doubled in the past decades. Recent estimates indicate that about 30% of children are overweight or obese.[5]

Insufficient physical activity is a proximate risk factor of childhood overweight.[6] In Canada, most children are not sufficiently active;[7] 9% of boys and 4% of girls accumulate the recommended 60 minutes of daily moderate-to-vigorous activity.[7] Promotion of physical activity is therefore a priority for the prevention of childhood overweight.

Parental beliefs and support for physical activity have been suggested as key areas for health promotion. Recent reviews report that parents influence children's physical activity behaviour by modeling and by supporting physical activity e.g., being active together, encouraging physical activity.[8, 9] However, research is limited and inconsistent when comparing the importance of parental physical activity beliefs and support for overweight relative to normal-weight children's physical activity.[10, 11] Furthermore, the literature lacks generalizability because studies have not been population-based. Additionally, parental beliefs and support for children's physical activity have not been associated with children's weight status.

To support the development of health promotion strategies and interventions for the prevention of childhood overweight, our primary objective is to use a population-based sample of children and parents to assess whether parental beliefs and support for physical activity are associated with childhood overweight. We also aim to assess the association of parental beliefs and support with physical activity, and whether this association is distinct for normal-weight compared to overweight children.

4.2 Methods

4.2.1 Study design/setting

Raising healthy Eating and Active Living (REAL) Kids Alberta is a population-based study of grade 5 children and parents in Alberta, Canada. The survey was conducted in 2008 and 2010 and employed a one-stage stratified random sampling design as described elsewhere.[12] In 2008, 148 of 184 (80.4%) schools participated. We sent 5,321 students home with surveys containing parental consent forms for their parent(s) to complete and return to school; 3,704 (70%) surveys were returned, 3,645 (98% of the 3,704) students received parental consent, and 3,421 children completed student surveys, resulting in a participation rate of 64%. We repeated data collection among grade 5 students and parents in 2010 from the schools that participated in 2008. In 2010, 7 schools were closed or not available to participate; we replaced these schools with 10 additional schools. We distributed 5,597 home surveys from 151 schools; 3,687 (66%) home surveys were returned, 3,656 (99% of the 3,687) students received parental consent to participate, and 3,389 children completed student surveys, resulting in a participation rate of 61%. Among these children, 3,300 in 2008 and 3,285 in 2010 had complete responses on parental beliefs and support, self-report physical activity, and BMI scores and were considered in the analysis.

4.2.2 Assessment of parental beliefs and support

The parent survey included three questions related to beliefs and support that were adapted from the activity-related parenting practices scale by Davison et al.[13] These included: 1) how much do you personally care about staying fit and exercising; 2) to what extent do you encourage your grade 5 child to be physically active; and 3) how often do you or another parent/guardian usually engage in physical activity together with your child. The questions we used are available at: www.REALKidsAlberta.ca

4.2.3 Assessment of outcome measures

4.2.3.1 Physical activity

The student survey included the Physical Activity Questionnaire for Older Children (PAQ-C). The PAQ-C is a validated 7-day recall instrument that provides a summary score for general physical activity for children, aged 8 to 14 years.[14-16] We derived the summary score by taking the mean score of 7 items, each scored on a 5-point scale. A summary score of 1 indicates low physical activity, whereas a score of 5 indicates high physical activity. The PAQ-C is a valid and reliable self-report measure for children's physical activity during the school year.[14, 15]

4.2.3.2 Overweight and obesity

Trained assistants measured children's standing height to the nearest 0.1 cm using stadiometers (Seca-Stadiometer, Germany) and body weight to the nearest 0.1 kg on calibrated digital scales (Health-o-meter, IL, USA). We asked children to remove their shoes for both measurements. BMI was calculated as kg/m^2. We defined overweight using the International Obesity Task Force BMI cut-off point established for children and youth.[17] The cut-off point is based on the health-related adult definition of overweight (BMI ≥25), but is adjusted to specific age and sex categories for children.

4.2.4 Confounding variables

Analyses were adjusted for the confounding potential of gender, survey completion year, parental education attainment, and combined household income (which is known to be high in Alberta) (Statistics Canada, 2011).

4.2.5 Data analysis

T-test and chi-square tests were used to test for differences between the 2008 and 2010 samples. Because observations were clustered within schools, we applied random effects models with students nested in schools. For each of the parental beliefs and support variables, we first applied univariable linear regression models to determine their associations with children's self-reported PA. Second, we applied multivariable linear regression models to adjust for the confounding effects of gender, parental educational attainment, household income, and year (Model 1). Third, we considered all predictors simultaneously to quantify their independent importance for children's self-reported PA (Model 2). We repeated these analyses stratified by normal-weight and overweight or obese children. Estimates of the effect size were derived from each model and are presented as estimates of the Partial Eta Squared. Last, to assess the effects of parental beliefs and support for PA on childhood over- weight, we applied logistic random effects models. Missing values for parental education attainment and household income were treated as separate covariate categories, however, we do not present their estimated values.

All analyses were weighted to account for the effect of the study design. Therefore, the estimates are population-based and apply to the grade 5 student population of Alberta, Canada. We used Stata Version 11 (Stata Corp, TX, USA) to perform the statistical analyses. The Health Research Ethics Board of the University of Alberta approved this study, including data collection and parental informed consent forms in 2008 and 2010.

4.3 Results

There were no differences between the 2008 and 2010 samples (Table 1). Boys reported higher levels of PA relative to girls ($p<0.001$). Increased parental care about staying fit and exercising, parental encouragement of PA, and parental engagement in PA with their child were associated with increased self-reported PA among children (Table 2). Parental encouragement of PA, and engagement in PA together were independent determinants of children's self- reported PA (Table 2: Model 2 beta coefficients).

Overweight children whose parents cared "quite a lot" about staying fit and exercising were reportedly significantly less active compared to normal-weight children whose parents cared "quite a lot" (Table 3: β=-0.07, 95% CI: -0.12, -0.03). Table 3 depicts similar findings for encouragement of PA (β=-0.04, 95% CI: -0.08, 0.01) and engagement in PA together (β=-0.07, 95% CI: -0.10, -0.03).

Parents and children engaging in PA together and parental care about staying fit and exercising were not associated with childhood overweight. The single statistically significant independent parent factor that was negatively associated with childhood overweight was increased parental encouragement. Relative to children whose parents encouraged PA "quite a lot", children whose parents encouraged PA "very much" had 22% lower odds of being over- weight (Table 4: Model 2 OR=0.78, 95% CI: 0.68-0.89).

4.4 Discussion

This study demonstrated that increases in parental care about staying fit and exercising, encouragement of PA, and parental engagement in PA with their child were associated with increased rates of self-reported PA among children. These gradients persisted after stratification based on weight status. A novel finding of this study was that the impact of parental encouragement of children's PA was also reflected in a lower prevalence of overweight.

Our findings are consistent with previous reviews indicating that parental beliefs and support for PA are positively related to children's PA, self-reported or otherwise.[8, 9] We found that parental engagement in PA and parental encouragement of PA were stronger predictors of children's reported PA than parental care about personal fitness. Other studies report similar findings.[18, 19] For example, McGuire et al.[19] showed that parental encouragement was significantly related to boys' and girls' PA, but parental concern about personal fitness was not related. These results are further supported by the fact that parental care about personal fitness reflects modeling behaviour,[20] which often less directly affects children's PA than more proximate forms of support.[21]

Colley et al.[22] reported that Canadian adults are not sufficiently active. Yet many parents report to engage in physical activities with their children. This study found that parental engagement in PA with their child was the strongest predictor of children's self-reported PA. This finding is consistent with some[23] but not all studies.[24] This discrepancy, however, may be an effect of children's age. The mean age of the children sampled by Adkins et al.[23] was 8.8 years, while the children sampled by Robbins et al.[24] were 11-14 years. There is some evidence[25] to suggest that as children move into adolescence, parental involvement in children's PA becomes less important and other types of support (e.g., encouragement and peer involvement) become more important. To our knowledge, this is the first study to report population-based results; therefore our results indicate that at a population level, targeting parents to encourage and spend time being active with their children may be an effective strategy to increase grade 5 children's PA.

We also found that increased parental care about staying fit and exercising, increased parental encouragement of PA, and increased engagement in activities were associated with increased rates of self-reported PA among both normal-weight and overweight children. These findings are consistent with those of others.[10, 26] However, the associations were distinct for normal-weight and overweight children. For example, the association between parental encouragement and self-reported PA, while positive among both overweight and normal-weight children, was stronger among normal-weight children. This seems consistent with a study that found that family social support was positively associated with PA in normal-weight boys, but not in overweight boys.[11] The importance of parental encouragement on overweight children's PA may be influenced by the tendency of these children to report more barriers to PA.[27] Conversely, the associations between parental engagement in PA together and reported PA behaviour among normal-weight and overweight children were similar, suggesting that parental engagement in PA may help overweight children to overcome barriers to PA.

We also showed that encouraging PA was negatively associated with childhood overweight. Studies indicate that parent encouragement is mediated through psychosocial attributes such as improved self-efficacy and liking of and attraction to activity.[18, 20] Health promotion strategies and interventions to increase children's PA and/or reduce childhood overweight should include pro- grams to teach parents how to effectively support their children to be physically active. Rhea recommended introducing overweight children gradually to enjoyable activities that will build their sense of self-efficacy.[28]

Strengths of our study include our large representative sample, generalizability of our results, measured heights and weights, and a high response rate for school-based research.[29] A limitation relates to the cross-sectional design, and necessitates caution with respect to interpretations of directionality and causality. Also, self-report measures are prone to bias and may produce socially desirable responses to questions surrounding parental beliefs and support, and an overestimation of children's PA.[30] Objective measures of PA (e.g., pedometers) would provide a more accurate estimate of children's PA, however, pedometers may be logistically and financially challenging in large population-based studies, as was the case in this study.

4.5 Conclusion

We showed the importance of parental beliefs and support for children's PA and body weight status. Health promotion strategies and programs that educate parents on how to effectively support their child in developing an active lifestyle may contribute to increasing PA and preventing overweight among children.

4.6 References

1. Tremblay MS, Inman JW, Willms JD. Relationships between physical activity, self-esteem, and academic achievements in ten- and eleven-year-old children. *Pediatr Exerc Sci.* 2000;11:312-23.
2. Florence MD, Asbridge M, Veugelers PJ. Diet quality and academic performance. *J School Health.* 2008;78:209-15.
3. Must A, Strauss RS. Risks and consequences of childhood and adolescent obesity. *Int J Obes Relat Metab Disord.* 1999;23:S2-S11.
4. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med.* 1997;337:869-73.
5. Tremblay MS, Shields M, Laviolette M, Craig CL, Janssen I, Connor Gorber S. Fitness of Canadian children and youth: Results from the 2007-2009 Canadian Health Measures Survey. *Health Rep.* 2010a;21:1-14.
6. Mayer J. Genetic, traumatic and environmental factors in the etiology of obesity. *Physiol Rev.* 1953;33:472-508.
7. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep.* 2011;22:1-9.
8. Edwardson CL, Gorely T. Parental influences on different types and intensities of physical activity in youth: A systematic review. *Pyschol Sport Exerc.* 2010;11:522-35.
9. Pugliese J, Tinsley B. Parental socialization of child and adolescent physical activity: A meta-analysis. *J Fam Psychol.* 2007;21:331-43.
10. De Bourdeaudhuij I, Lefevre J, Defroche B, Wijndaele K, Matton L, Philippaerts R. Physical activity and psychosocial correlates in normal weight and overweight 11 to 19 year olds. *Obes Res.* 2005;13:1097-105.
11. Kitzman-Ulrich H, Wilson DK, Van Horn ML, Lawman HG. Relationship of body mass index and psychosocial factors on physical activity in underserved adolescent boys and girls. *Health Psychol.* 2010;29:506-13.
12. Simen-Kapeu A, Veugelers PJ. Should public health interventions aimed at reducing childhood overweight and obesity be gender-focused? *BMC Public*

Health. 2010;10:340-47.

13. Davison KK, Cutting TM, Birch LL. Parents' activity-related parenting practices predict girls' physical activity. *Med Sci Sport Exerc.* 2003;35:1589-95.

14. Crocker PRE, Bailey DA, Faulkner RA, Kowalski KC, McGrath R. Measuring general levels of physical activity: Preliminary evidence for the Physical Activity Questionnaire for Older Children. *Med Sci Sports Exerc.* 1997;29:1344-49.

15. Kowalski KC, Crocker PRE, Faulkner RA. Validation of the Physical Activity Questionnaire for Older Children. *Pediatr Exerc Sci.* 1997;9:174-86.

16. Kowalski KC, Crocker PRE, Donen RM. The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescence (PAQ-A) Manual, 2004. Available at: http://hkin.educ.ubc.ca/behavioural/PAQ%20manual.pdf (Accessed July 2011).

17. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ.* 2000;320:1240-1243.

18. Brustad RJ. Who will go out and play? Parental and psychological influences on children's attraction to physical activity. *Pediatr Exerc Sci.* 1993;5:210-23.

19. McGuire MT, Hannan PJ, Neumark-Sztainer D, Falkner Cossrow NH, Story M. Parental correlates of physical activity in a racially/ethnically diverse adolescent sample. *J Adolesc Health.* 2002;30:253-61.

20. Brustad RJ. Attraction to physical activity in urban schoolchildren: Parental socialization and gender influences. Res Q Exerc Sport. 1996;67:316-23.

21. Trost SG, Sallis JF, Pate RR, Freedson PA, Taylor WC, Dowda M. Evaluating a model of parental influence on youth physical activity. *Am J Prev Med.* 2003;25:277-82.

22. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian adults: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep.* 2011;22:1-8.

23. Adkins S, Sherwood NE, Story M, Davis M. Physical activity among African-American girls: The role of parents and the home environment. *Obes Res.* 2004;12:38S-45S.

24. Robbins LB, Stommel M, Hamel LM. Social support for physical activity of middle school students. *Public Health Nurs.* 2008;25:451-60.

25. Duncan SC, Duncan TE, Strycker LA. Sources and types of social support in youth physical activity. *Health Psychol.* 2005;24:3-10.

26. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc.* 2000;32:963-75.

27. Trost SG, Kerr LM, Ward DS, Pate RR. Physical activity and determinants of physical activity in obese and non-obese children. *Int J Obes.* 2001;25:822-29.

28. Rhea DJ. Physical activity and body image of female adolescents. *J Phys Educ Rec Dance.* 1998;69:27-31.

29. Finn-Aage E, Melde C, Taylor TJ, Peterson D. Active parental consent in school-based research: How much is enough and how do we get it? *Eval Rev.* 2008;32:335-62.

30. Toriano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc.* 2008;40:181-88.

4.7 Tables

Table 4.1: Descriptive characteristics of grade 5 children and their parent(s) in Alberta, Canada including means (95% confidence intervals) and prevalence.

	2008 Prevalence (n = 3300)	**2010 Prevalence** (n = 3285)	**Combined Prevalence** (n=6585)
Mean age	10.67 (10.66;10.68)	10.88 (10.87;10.89)	10.78 (10.77;10.79)
Proportion boys, %	48.3	49.2	48.7
Overweight, %	28.5	27.4	27.9
Obese, %	6.7	8.8	7.7
Mean PAQ-C	3.30 (3.28;3.32)	3.32 (3.30;3.34)	3.31 (3.30;3.32)
Parental education, %			
Secondary or less	26.9	25.1	26.0
College Diploma	39.7	39.2	39.5
University/graduate	33.4	35.7	34.5
Household income, %			
<$50,000	24.0	24.0	24.0
$50,001-$75,000	17.7	17.6	17.6
$75,001-$100,000	22.0	20.4	21.3
>$100,001	36.3	38.0	37.1

Table 4.2: Prevalence and associations (beta coefficients and 95% confidence interval) of parental beliefs and support for grade 5 children's PA in Alberta, Canada.

	Prevalence	Univariable			Multivariable					
					Model 1*			Model 2†		
		β	95% CI	Effect Size‡	β	95% CI	Effect Size‡	β	95% CI	Effect Size‡
Care about staying fit and exercising										
Not at all /A little	23.1	-0.16	-0.19; -0.12	0.016	-0.15	-0.18; -0.11	0.014	-0.02	-0.05; 0.01	<0.001
Quite a lot	46.1	0.00	-	-	0.00	-	-	0.00	-	-
Very much	30.8	0.15	0.11; 0.19	0.015	0.14	0.11; 0.18	0.013	0.02	-0.01; 0.05	<0.001
Encourage PA										
Not at all /A little	13.1	-0.28	-0.33; -0.24	0.033	-0.27	-0.31; -0.22	0.030	-0.19	-0.23; -0.15	0.020
Quite a lot	45.0	0.00	-	-	0.00	-	-	0.00	-	-
Very much	41.9	0.22	0.19; 0.25	0.040	0.21	0.17; 0.24	0.036	0.13	0.10; 0.16	0.019
Engage in PA										
Never/< 1	39.3	-0.44	-0.47; -0.41	0.163	-0.44	-0.47; -0.41	0.171	-0.40	-0.43; -0.37	0.147
1-3 times/week	51.7	0.00	-	-	0.00	-	-	0.00	-	-
≥ 4 times/week	9.0	0.34	0.30; 0.38	0.035	0.36	0.32; 0.41	0.045	0.33	0.28; 0.37	0.040

Note: We combined responses to the first two categories for each question due to small cell sizes.

* - Model 1 is adjusted for gender, household income, parental educational attainment and year of data collection

† - Model 2 is adjusted for parental care about staying fit and exercising, encourage PA, engage in PA together, gender, household income, parental educational attainment, and year of data collection.

‡ - Partial Eta squared

Table 4.3: Prevalence and associations (beta coefficients and 95% confidence intervals) of parental beliefs and support for normal weight and overweight (including obese) grade 5 children's PA in Alberta, Canada.

		Prevalence	Univariable			Multivariable *		
			β	95% CI	Effect Size‡	β	95% CI	Effect Size‡
Care about staying fit and exercising	***Normal Weight***							
	Not at all /A little bit	16.1	-0.15	-0.20; -0.11	0.011	-0.14	-0.19; -0.10	0.010
	Quite a lot	33.0	0.00	-	-	0.00	-	-
	Very Much	23.1	0.14	0.11; 0.18	0.011	0.13	0.10; 0.17	0.009
	Overweight/Obese							
	Not at all /A little bit	7.0	-0.24	-0.29; -0.19	0.014	-0.23	-0.28; -0.18	0.013
	Quite a lot	13.1	-0.08	-0.12; -0.04	0.003	-0.07	-0.12; -0.03	0.003
	Very Much	7.7	0.09	0.02; 0.16	<0.001	0.09	0.02; 0.16	<0.001
Encourage PA	***Normal Weight***							
	Not at all /A little bit	8.9	-0.29	-0.34; -0.23	0.024	-0.27	-0.32; -0.21	0.022
	Quite a lot	31.5	0.00	-	-	0.00	-	-
	Very Much	31.7	0.23	0.19; 0.27	0.033	0.22	0.18; 0.26	0.030
	Overweight/Obese							
	Not at all /A little bit	4.3	-0.32	-0.40; -0.24	0.016	-0.30	-038; -0.22	0.014
	Quite a lot	13.5	-0.04	-0.08; 0.003	0.001	-0.04	-0.08; 0.01	0.001
	Very Much	10.1	0.13	0.07; 0.19	0.004	0.13	0.07; 0.19	0.003
Engage in PA together	***Normal Weight***							
	Not at all /A little bit	28.0	-0.43	-0.47; -0.40	0.117	-0.43	-0.46; -0.40	0.123
	Quite a lot	37.7	0.00	-	-	0.00	-	-
	Very Much	6.4	0.32	0.27; 0.37	0.025	0.34	0.30; 0.39	0.032
	Overweight/Obese							
	Not at all /A little bit	11.3	-0.53	-0.58; -0.48	0.108	-0.53	-0.58; -0.48	0.111
	Quite a lot	14.0	-0.07	-0.11; -0.04	0.004	-0.07	-0.10; -0.03	0.003
	Very Much	2.6	0.32	0.23; 0.41	0.007	0.35	0.26; 0.43	0.011

* - Adjusted for gender, household income, parental educational attainment, and year of data collection.

‡ - partial Eta squared

Table 4.4. Prevalence and associations (odds ratio and 95% confidence interval) of parental beliefs and support for childhood overweight among grade 5 children in Alberta, Canada.

	Prevalence	Univariable		Multivariable			
				Model 1*		Model 2†	
		OR	95% CI	OR	95% CI	OR	95% CI
Care staying fit & exercising							
Not at all /A little bit	23.1	1.08	0.93;1.25	1.06	0.91;1.23	1.02	0.87;1.20
Quite a lot	46.1	1.00	-	1.00	-	1.00	-
Very much	30.8	0.87	0.75;1.02	0.90	0.77;1.05	0.98	0.84;1.15
Encourage PA							
Not at all /A little bit	13.1	1.13	0.95;1.34	1.11	0.93;1.32	1.10	0.92;1.33
Quite a lot	45.0	1.00	-	1.00	-	1.00	-
Very much	41.9	0.76	0.67;0.87	0.78	0.69;0.89	0.78	0.68;0.89
Engage in PA together							
Never/< 1 time/week	39.3	1.07	0.93;1.23	1.05	0.91;1.21	1.00	0.87;1.15
1-3 times/week	51.7	1.00	-	1.00	-	1.00	-
≥ 4 time/week	8.98	1.03	0.82;1.30	1.01	0.80;1.27	1.07	0.85;1.34

* - Model 1 is adjusted for gender, household income, parental educational attainment and year of data collection.

† - Model 2 is adjusted for parental care about staying fit and exercising, encourage PA, engage in PA together, gender, household income, parental educational attainment, and year of data collection.

5 The importance of parental beliefs and support for objectively measured physical activity on school days and weekend days among Canadian children

Vander Ploeg KA, Kuhle S, Maximova K, McGavock J, Wu B, Veugelers PJ. The importance of parental beliefs and support for objectively measured physical activity on school days and weekend days among Canadian children. *BMC Public Health* 2013;13:1132-1138.

5.1 Introduction

Regular physical activity is associated with an array of health benefits for children.[1] Unfortunately, most children in Canada are not sufficiently active. Currently, only 7% of boys and 3% of girls accumulate the recommended 13,500 steps per day at least 6 days a week.[2] We have previously demonstrated that these trends are significantly worse on weekend days, relative to weekdays.[3] These trends are concerning as low levels of physical activity during childhood contribute to obesity and comorbid conditions in adulthood.[4] As such, increasing children's physical activity levels, particularly on weekend days, continues to be a priority for improving child health outcomes.

It is well established that parental influences are essential to the behaviours and physical activity of their children.[5-7] Children's physical activity levels have been shown to be greater when parents are active, encourage them to be active, and engage in activities with them.[6, 8-11] Reviews demonstrate that childhood is an important time to establish healthy behaviours given that behaviours established and practiced in childhood track into adulthood.[12, 13] However, as children spend substantial time at school, parents may have more opportunities to influence children's physical activity on weekend days than on school days. To our knowledge, the importance of parental beliefs and support as a correlate of children's weekend day physical activity has never been studied.

To address this knowledge gap, we relied on recently collected cross-sectional data to test the hypothesis that parental beliefs and support for physical activity are positively associated with physical activity levels in grade five students on school and weekend days. We also hypothesized that this association is distinct for school days and weekend days.

5.2 Methods

5.2.1 Study design/setting

Raising healthy Eating and Active Living Kids in Alberta (REAL Kids Alberta) is a population-based study of grade five children and their parents in the Canadian province of Alberta. In 2008, the REAL Kids Alberta survey included 148 randomly selected schools from across Alberta as described elsewhere.[14] In 2009, we selected and invited a convenient sample of 20 of the 148 schools, located in the city of Edmonton and surrounding areas, to participate in an additional survey that included objective measures of physical activity. We also invited grade five students from 10 schools participating in the Alberta Program Promoting active Living and healthy Eating in Schools (APPLE Schools).[15] We repeated data collection among grade five students and parents in 2011 from the same schools that participated in 2009. In 2009 and 2011 combined, we sent 2,502 parent consent forms and surveys home with students for their parents to complete and return to school; 2,045 (81.7%) home surveys were returned, 2,028 (99.2%) students received parental consent to participate. Student assent to participate was obtained from 1,991 (98.2%) children, and 1,977 (99.3%) children completed student surveys, resulting in an overall participation rate of 79.0%. Pedometers were distributed to the 1,991 students with parent consent and student assent, 1,783 pedometers were returned, providing crude hourly step counts; 210 (10.5%) pedometers were lost or malfunctioned. The Health Research Ethics Board of the University of Alberta approved this study, including data collection and parental informed consent forms.

5.2.2 Assessment of parental beliefs and support

The parent survey included three validated questions related to beliefs and support that were adapted from the activity-related parenting practices scale by Davison et al.[16] These included: 1) how much do you personally care about staying fit and exercising (a little bit; quite a lot; very much); 2) to what extent do you encourage your grade five child to be physically active (a little bit; quite a lot; very much); and 3) how often do you or another parent/guardian usually engage in physical activity together with your child (less than 1 time/week; 1-3 times/week; 4 or more times/week). The questionnaires we used are available on the project's website: http://www.REALKidsAlberta.ca.

5.2.3 Assessment of physical activity

We used Omron HJ-720ITC (Ontario, Canada) pedometers to measure physical activity objectively. This pedometer records steps hourly, automatically resets at midnight, and can store data for 42 days. Further rationale for selecting this pedometer are described in detail elsewhere.[3] The accuracy and validity of the Omron pedometer has been demonstrated under various conditions.[17-19] Students wore pedometers for nine consecutive days on their right hip directly in line with their right knee during all waking hours unless showering, swimming, or taking part in activities in which an adult deemed it unsafe to wear. Pedometer recordings from the first and ninth days were not considered as, on these days, the students started or ended wearing the pedometers, and thus recordings are not available for the full day. Students also kept a diary of their daily activities, including the duration of each activity and whether or not the pedometer was worn (available at: www.REALKidsAlberta.ca). Trained evaluation assistants returned to schools on the ninth day to collect pedometers and download data to computers. Pedometer recordings were stratified into school day (Monday-Friday) and weekend day (Saturday, Sunday, and holidays) categories.

5.2.4 Confounding variables

Evaluation assistants measured children's standing height to the nearest 0.1 cm using stadiometers (Seca-Stadiometer, Germany) and body weight to the nearest 0.1 kg on calibrated digital scales (Health-o-meter, IL, USA). Children removed their shoes for both measurements. Body Mass Index (BMI) was calculated as kg/m^2. Overweight was defined using the International Obesity Task Force BMI cut-off point established for children and youth.[20] The cut-off point is based on the health-related adult definition of overweight (BMI ≥ 25), but is adjusted to specific age and sex categories for children. Analyses were adjusted for the confounding potential of parental educational attainment, household income, and year of data collection.

5.2.5 Data processing

For our analyses we only considered pedometer recordings when worn for a minimum of 8 hours per day.[21] Additionally, we required pedometer recordings on at least two school days and one weekend day (weekend and/or holiday).[22] When these conditions were met, students' pedometer-measured steps were complemented with step-equivalents of non-ambulatory and non-wear time activities recorded in students' activity diaries. Briefly, we assigned each activity recoded in activity diaries a youth-specific metabolic equivalent task (MET) unit.[23] Next, we categorized activities by intensity (i.e., moderate, moderate-to-vigorous, vigorous)[24, 25] and assigned a step per minute value to each category.[26] Adult METS units were used when youth specific values were not available.[24] When students forgot to wear their pedometer and complete their activity diary, we imputed information from the same hour(s) on other randomly selected valid days. Steps were only imputed within an individual and within school days and weekend days. This method of imputation has been shown to replace data more accurately than traditional group-centered methods that replace missing data with the group mean.[27] These procedures are described in further detail elsewhere.[3]

In 2009 and 2011 combined, we had information of pedometer step counts and parental reporting of physical activity-related beliefs and support for 717 girls and 638 boys.

5.2.6 Data analysis

T-tests and chi-square tests were used to test for data collection year and sex differences. Because observations of students are clustered within schools, we applied random effects models with students nested in schools. For each of the parent belief and support variables, we first applied univariable linear regression models to determine their associations with girls' and boys' step-counts taken on weekend days and on school days. Second, we applied multivariable linear regression models to adjust for the confounding potential of parental educational attainment, household income, and year of data collection (referred to as Model 1). Last, we considered parent beliefs and support variables simultaneously while adjusting for the above confounders to quantify their independent importance for children's step-counts (referred to as Model 2). For each of the parent belief and support variables we used the middle response category as the reference group for analyses presented in Tables 2 and 3.

In a combined analysis, we used an interaction term (defined as the product of school day/weekend day and the parent belief and support variables) in the adjusted linear regression models to quantify the differential effect of beliefs and support on physical activity during school days versus weekend days.

Missing values for parental education attainment and household income were treated as separate covariate categories, however, we do not present their estimated values. We used Stata Version 12 (Stata Corp, TX, USA) to perform the statistical analyses.

5.3 Results

Participant characteristics are reported in Table 1. The average daily step count was higher on school days than on weekend days (12,868 ± 4006 vs. 11763 ± 6636 steps/day $p<0.001$). Boys achieved significantly more steps per day than girls on school days (13844 ± 4424 vs. 12000 ± 3366 $p<0.001$) and on weekend days (12716 ± 7488 vs. 10914 ± 5645 $p<0.001$). Parents also reported to encourage boys to be physically active significantly more than girls ($p<0.001$). There were no statistically significant differences in the data collected in 2009 and 2011.

Girls. On school days, increased parental encouragement of physical activity, and increased parental engagement in physical activity together were significantly and positively associated with girls' daily step counts (Table 2: Model 1). Girls whose parents encouraged physical activity "very much" took an additional 632 (95% CI: 108, 1155) steps per day on school days relative to girls whose parents encouraged them "quite a lot". Additionally, on school days, girls whose parents engaged in physical activity with them more than four times per week achieved an additional 890 (95% CI: 67, 1712) steps per day relative to girls whose parents engaged in physical activity with them one to three times per week. On weekend days, increased parental encouragement of physical activity was the only positive association with girls' daily steps counts (β = 997, 95%CI: 130, 1864) that appeared to be statistically significant. Girls whose parents encouraged them "very much" to be physically active took an additional 997 (95% CI: 130, 1864) steps per day on weekend days than girls whose parents encouraged them "quite a lot". Model 2 of Table 2 reveals that the three parental behaviours (parental care for staying fit and exercising, parental encouragement and parental engagement) are correlated such that none of the three behaviours has a statistically significant effect on girls' step counts over and above that of the other two behaviours.

Boys. On school days, increased encouragement of physical activity was associated with daily step counts. This association was statistically significant (Table 3). Boys whose parents encouraged physical activity "very much" took an additional 1373 (95% CI: 606, 2139) steps per day on school days relative to boys whose parents encouraged physical activity "quite a lot". This association was independent of parental care for staying fit and exercising and parental engagement in physical activity (Table 3: Multivariable Model 2). On weekend days, increased parental care about staying fit and exercising was positively associated with boys' daily step counts (Table 3). Boys whose parents reported to care "very much" about staying fit and exercising took an additional 1381 (95% CI: 85, 2676) (Table 2) steps per day on weekend days relative to boys whose parents reported to care "quite a lot". Also, on weekend days, decreased parental engagement in physical activity was negatively associated with boys' daily step counts (Table 3). That is, boys whose parents engaged in physical activity with them less than once per week took 1367 fewer steps per day on weekend days relative to boys whose parents engaged in physical activity with them one to three times per week (95% CI: -2643, -90). This association was independent of parental care for staying fit and exercising and parental encouragement (Table 3: Multivariable Model 2).

There were no significant interactions between parental care for staying fit and exercising, parental encouragement of physical activity, or engagement in physical activity together and girls' "school day/weekend day" step counts. Parental engagement in physical activity and boys' "school day/weekend day" physical activity was the single statistically significant interaction. This interaction remained significant after adjusting for potential confounders. Boys whose parents engaged in physical activity with them less than once per week took 1475 (95% CI: -2609, -341) fewer steps per day on weekend days than they did on school days.

5.4 Discussion

This study demonstrates the importance of parental beliefs and support for boys' and girls' physical activity on school days and on weekend days. This study demonstrates that parental beliefs and support are important targets for prevention strategies to increase children's physical activity, which is particularly relevant for weekend days, as children's activity levels appear to be low during this window of time.

We confirmed children's physical activity levels to be lower on weekend days than on school days.[28-32] In addition, we observed that parental beliefs and support are positively associated with boys' and girls' physical activity achieved on weekend days. For example, we found that girls whose parents reported to encourage physical activity "very much" were significantly more active on weekend days than girls whose parents reported to encourage physical activity "quite a lot". Similarly, we found that boys whose parents reported to care "very much" about staying fit and exercising were significantly more active on weekend days than boys whose parents reported to care "quite a lot". To our knowledge, this had not been shown in the literature. These results suggest that specifically targeting parents to encourage and support their child's physical activity behaviour may be an effective strategy to improve physical activity.

The associations between parental beliefs and support and weekend day physical activity were distinct for boys and girls. For example, parental encouragement was positively associated with girls' weekend physical activity (Model 1) while parental care for staying fit and exercising was positively associated with boy's weekend physical activity (Model 1). We observed that associations tended to be stronger among boys than girls. McGuire et al.[33] also found that parental-adolescent relationships were stronger among boys than girls. Further, we observed that parents reported to encourage boys to be physically active significantly more than they encouraged girls. Trost et al.[34] found that parents reported significantly higher levels of support and perceived importance for boys' physical activity compared to girls' physical activity. This suggests the importance of health promotion messages that are specific for girls and boys[14], and that educate parents on the importance of physical activity for both boys and girls. Community-based physical activity programs occurring on weekends that involve children and their parents may help to increase boys' and girls' physical activity levels on weekends. Health promotion messages should also consider targeting parenting practices as they relate to encouragement to educate parents on how to effectively support their daughters' activity-related behaviours as girls' activity levels lag behind that of boys.

Among boys on the weekend, we found that boys whose parents reported to engage in physical activities with them more than four times per week were less active than boys whose parents reported to engage in activities with them between one and three times per week. This is not supported in the literature; others report positive associations between parental engagement in activities and children's physical activity.[6, 8-11] The finding we report here is counter intuitive and may be a result of reverse causation, meaning these parents have recognized their sons to be in a less active subgroup and are intervening in an attempt to raise their activity levels. This seems consistent with our earlier observations, though in a different sample of children, where parents engaged more in activity with their overweight daughters or sons than with their normal weight children.[11] This is an interesting point and warrants further investigation.

Strengths of our study include the use of time-stamped pedometers, a large sample size, and high participation rates for school-based research.[35] A further strength of our study is the adjustments made to raw pedometer-measured steps from activities recorded by students in daily activity logs. There are a few limitations however, that should be acknowledged. Although selected from a population-based sample, the sample of students in this study is not representative of the Alberta population. As such, caution is warranted when generalizing the present results. The cross-sectional design is a limitation and necessitates caution with respect to interpretations of directionality and causality. Furthermore, while the pedometer used in this study has been validated among adults under various conditions,[17-19] it has not specifically been validated among 10-11 year-old children. However, because all children wore the same pedometer it is unlikely that this influenced the observed effect size.[36] Also, self-report measures are prone to bias and may produce socially desirable responses to questions surrounding parental beliefs and support. This limitation is acknowledged in the literature.[37] Additionally, given that we did not quantify "how much" parents encourage their child to be active, it is possible that broader parenting practices or styles were captured rather than the actual encouragement itself.[38] This warrants further investigation. To better inform health promotion messages and interventions, future studies may also consider assessing differences in the provisions of encouragement, engagement, and care between boys and girls.

5.5 Conclusion

We showed that parental beliefs and support for physical activity are associated with children's physical activity on school days and on weekend days. Health promotion strategies and programs that educate parents on how to effectively support their child in developing an active lifestyle may contribute to increasing physical activity levels.

5.6 References

1. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7 40.
2. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep*. 2011;22 (1):15-23.
3. Vander Ploeg KA, Wu B, McGavock J, Veugelers PJ. Physical activity among Canadian children on school days and nonschool days. *J Phys Act Health*. 2012;9 (8):1138-1145.
4. Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. *Pediatr*. 2007;120 Suppl 4 S193-S228.
5. Brustad RJ. Who Will Go Out and Play? Parental and psychological influences on children's attraction to physical activity. *Pediatr Exerc Sci*. 1993;5 210-223.
6. Prochaska JJ, Rodgers MW, Sallis JF. Association of parent and peer support with adolescent physical activity. *Res Q Exerc Sport*. 2002;73 (2):206-210.
7. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc*. 2000;32 (5):963-975.
8. Duncan SC, Duncan TE, Strycker LA. Sources and types of social support in youth physical activity. *Health Psychol*. 2005;24 (1):3-10.
9. Moore LL, Lombardi DA, White MJ, Campbell JL, Oliveria SA, Ellison RC. Influence of parents' physical activity levels on activity levels of young children. *J Pediatr*. 1991;118 (2):215-219.
10. Sallis JF, Alcaraz JE, McKenzie TL, Hovell MF, Kolody B, Nader PR. Parental behavior in relation to physical activity and fitness in 9-year-old children. *Am J Dis Child*. 1992;146 (11):1383-1388.
11. Vander Ploeg KA, Maximova K, Kuhle S, Simen-Kapeu A, Veugelers PJ. The importance of parental beliefs and support for physical activity and body weights of children: a population-based analysis. *Can J Public Health*. 2012;103 (4):e277-e281.
12. Jones RA, Hinkley T, Okely AD, Salmon J. Tracking physical activity and sedentary behavior in childhood: a systematic review. *Am J Prev Med*.

2013;44 (6):651-658.

13. Telama R. Tracking of physical activity from childhood to adulthood: a review. *Obes Facts*. 2009;2 (3):187-195.

14. Simen-Kapeu A, Veugelers PJ. Should public health interventions aimed at reducing childhood overweight and obesity be gender-focused? *BMC Public Health*. 2010;10 340.

15. Fung C, Kuhle S, Lu C et al. From “best practice” to “next practice”: the effectiveness of school-based health promotion in improving healthy eating and physical activity and preventing childhood obesity. *Int J Behav Nutr Phys Act*. 2012;9 27.

16. Davison KK, Cutting TM, Birch LL. Parents’ activity-related parenting practices predict girls’ physical activity. *Med Sci Sports Exerc*. 2003;35 (9):1589-1595.

17. Hasson R, Haller J, Pober D, Staudenmayer J, Freedson P. Validity of the Omron HJ-112 pedometer during treadmill walking. *Med Sci Sports Exerc*. 2009;41 (4):805.

18. Holbrook E, Barreira T, Kang M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci Sports Exerc*. 2009;41 (3):670.

19. Zhu W, Lee M. Invariance of wearing location of Omron-BI pedometers: a validation study. *J Phys Act Health*. 2010;7 (6):706.

20. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320 (7244):1240-1243.

21. Penpraze V, Reilly JJ, MacLean CM, Montgomery C, Kelly LA. Monitoring of physical activity in young children: how much is enough? *Pediatr Exerc Sci*. 2006;18 (4):483-491.

22. Craig CL, Tudor-Locke C, Cragg S, Cameron C. Process and treatment of pedometer data collection for youth: the Canadian Physical Activity Levels among Youth study. *Med Sci Sports Exerc*. 2010;42 (3):430-435.

23. Ridley K, Ainsworth BE, Olds TS. Development of a compendium of energy expenditures for youth. *Int J Behav Nutr Phys Act*. 2008;5 (1):45.

24. Ainsworth BE, Haskell WL, Whitt MC et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32 (9;S1):S498-S504.

25. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed?

Med Sci Sports Exerc. 2000;32 (2):426-431.

26. Jago R, Watson K, Baranowski T et al. Pedometer reliability, validity and daily activity targets among 10- to 15-year-old boys. *J Sports Sci*. 2006;24 (3):241-251.

27. Kang M, Zhu W, Tudor-Locke C, Ainsworth BE. An experimental determination of the best missing-value recovery method in assessing physical activity using pedometers. *Res Q Exerc Sport*. 2003;74 (1

28. Duncan MJ, Al-Nakeeb Y, Woodfield L, Lyons M. Pedometer determined physical activity levels in primary school children from central England. *Prev Med*. 2007;44 (5):416-420.

29. McGall SE, McGuigan MR, Nottle C. Contribution of free play towards physical activity guidelines for New Zealand primary school children aged 7-9 years. *Br J Sports Med*. 2011;45 (2):120-124.

30. Nyberg GA, Nordenfelt AM, Ekelund U, Marcus C. Physical activity patterns measured by accelerometry in 6- to 10-yr-old children. *Med Sci Sports Exerc*. 2009;41 (10):1842-1848.

31. Rowe DA, Mahar MT, Raedeke TD, Lore J. Measuring physical activity in children with pedometers: Reliability, reactivity, and replacement of missing data. *Pediatr Exerc Sci*. 2004;16 (4):343-354.

32. Rowlands AV, Pilgrim EL, Eston RG. Patterns of habitual activity across weekdays and weekend days in 9-11-year-old children. *Prev Med*. 2008;46 (4):317-324.

33. McGuire MT, Hannan PJ, Neumark-Sztainer D, Cossrow NH, Story M. Parental correlates of physical activity in a racially/ethnically diverse adolescent sample. *J Adolesc Health*. 2002;30 (4):253-261.

34. Trost SG, Sallis JF, Pate RR, Freedson PS, Taylor WC, Dowda M. Evaluating a model of parental influence on youth physical activity. *Am J Prev Med*. 2003;25 (4):277-282.

35. Finn-Aage E, Melde C, Taylor TJ, Peterson D. Active parental consent in school-based research: how much is enough and how do we get it. *Evaluation Review*. 2008;32 (4):335-362.

36. Rothman KJ, Greenland S, Professor TLLA. *Modern Epidemiology*. ThirdLippincott Williams & Wilkins; 2008.

37. Baranowski T, O'Connor T, Hughes S et al. Houston. We have a problem! Measurement of parenting. *Child Obes*. 2013;9 Suppl S1-S4.

38. Trost SG, McDonald S, Cohen A. Measurement of general and specific approaches to physical activity parenting: a systematic review. *Child Obes*.

2013;9 Suppl S40-S50.

5.7 Tables

Table 5.1 Characteristics of grade five students participating in the study.

	Mean ± SD/Prevalence	
	Girls (n=717)	**Boys (n=638)**
Age	10.9 ± 0.4	10.9 ± 0.4
BMI of child *	19.1 ± 3.5	19.7 ± 4.4
Overweight (%) *	29.2	34.6
Obese (%) *	7.5	10.8
Physical Activity[1]		
School Day *	12,000 ± 3,366	13,844 ± 4,424
Non-School Day *	10,914 ± 5,645	12,716 ± 7,488
Parent cares about staying fit and exercising		
A little bit	21.7	19.1
Quite a lot	43.4	45.9
Very much	34.9	35.0
Parent encourages their child to be PA		
A little bit	13.6	11.3
Quite a lot	44.1	38.9
Very much	42.4	49.8
Parent engages in PA with their child *		
<1 time/week	40.3	38.8
1-3 times/week	49.0	50.5
≥4 times/week	10.7	10.7
Parental education attainment		
Secondary or less	26.7	22.4
College	42.0	40.5
University and Graduate	31.3	37.1
Household income		
<50,000	21.5	19.2
50,001-75,000	15.9	14.3
75,001-100,000	17.4	17.3
>100,001	45.3	49.3

[1] – pedometer-measured steps adjusted for non-ambulatory activities, non-wear time activities, and missing data.

* – considered statistically significant at P<0.05

Table 5.2 The association (beta coefficient and 95% confidence interval) of parent belief and support with grade five girls' physical activity[1] (PA) on school days and weekend days.

	School Days						Weekend Days					
	Univariable		Multivariable				Univariable		Multivariable			
			Model 1[2]		Model 2[3]				Model 1[2]		Model 2[3]	
	β	(95% CI)	β	(95% CI)	β	(95% CI)	β	(95% CI)	β	(95% CI)	β	(95% CI)
Care stay fit & exercise												
A little bit	-506	-1151, 140	-416	-1057, 224	-238	-896, 421	-745	-1806, 316	-605	-1665, 454	-471	-1561, 619
Quite a lot[4]	0	-	0	-	0	-	0	-	0	-	0	-
Very much	347	-214, 907	339	-218, 897	34	-576, 644	605	-315, 1526	613	-309, 1535	170	-839, 1179
Encourage PA												
A little bit	-643	-1408, 122	-620	-1380, 140	-503	-1291, 285	-719	-1977, 539	-675	-1932, 582	-639	-1942, 665
Quite a lot[4]	0	-	0	-	0	-	0	-	0	-	0	-
Very much	616*	89, 1143	632*	108, 1155	546	-33, 1126	970*	101, 1839	997*	130, 1864	856	-103, 1816
Engage in PA												
<1 time/week	-8	-531, 515	19	-497, 535	222	-307, 752	409	-448, 1267	450	-402, 1303	652	-224, 1529
1-3 times/week[4]	0	-	0	-	0	-	0	-	0	-	0	-
>4 time/week	727*	-103, 1558	890*	67, 1712	712	-120, 1543	942	-420, 2304	1161	-198, 2519	806	-571, 2183

[1] – pedometer-measured steps adjusted for non-ambulatory activities, non-wear time activities, and missing data.
[2] – Model 1 is adjusted for household income, parental educational attainment and year of data collection
[3] – Model 2 is adjusted for parental care about staying fit and exercising, encourage PA, engage in PA together, household income, parental educational attainment, and year of data collection.
[4] – reference category
* – considered statistically significant at P<0.05

Table 5.3 The association (beta coefficient and 95% confidence interval) of parent belief and support with grade five boys' physical activity[1] (PA) on school days and weekend days.

	School Days						Weekend Days					
	Univariable		Multivariable				Univariable		Multivariable			
			Model 1[2]		Model 2[3]				Model 1[2]		Model 2[3]	
	β	(95% CI)	β	(95% CI)	β	(95% CI)	β	(95% CI)	β	(95% CI)	β	(95% CI)
Care stay fit & exercise												
A little bit	-618	-1542,306	-654	-1582,273	-430	-1394,534	-505	-2105,1095	-658	-2225,910	-168	-1811,1475
Quite a lot[4]	0	-	0	-	0	-	0	-	0	-	0	-
Very much	505	-260,1270	453	-316,1222	79	-718,877	1439*	121,2758	1381*	85,2676	1306	-50,2661
Encourage PA												
A little bit	-269	-1418,880	-286	-1436,864	-165	-1358,1028	-944	-2940,1051	-1032	-2980,917	-563	-2570,1445
Quite a lot[4]	0	-	0	-	0	-	0	-	0	-	0	-
Very much	1408*	690,2126	1372*	653,2092	1373*	606,2139	939	-322,2201	936	-300,2171	625	-686,1935
Engage in PA												
<1 time/week	-240	-971,491	-246	-973,482	112	-641,865	-1680*	-2937,-424	-1669*	-2888,-450	-1367*	-2643,-90
1-3 times/week[4]	0	-	0	-	0	-	0	-	0	-	0	-
>4 time/week	492	-650,1635	566	-571,1702	264	-882,1410	-1276	-3254,701	-1076	-2998,846	-1350	-3309,608

[1] – pedometer-measured steps adjusted for non-ambulatory activities, non-wear time activities, and missing data.
[2] – Model 1 is adjusted for household income, parental educational attainment and year of data collection
[3] – Model 2 is adjusted for parental care about staying fit and exercising, encourage PA, engage in PA together, household income, parental educational attainment, and year of data collection.
[4] – reference category
* – considered statistically significant at $P<0.05$

6 School-based health promotion and physical activity during and after school hours

Vander Ploeg KA, McGavock J, Maximova K, Veugelers PJ. School-based health promotion and physical activity during and after school hours. *Pediatrics* 2014;133(2):1-9.

6.1 Introduction

Physical activity is a primary determinant of optimal growth and health in children. Children who achieve 60 minutes of moderate-to-vigorous physical activity (MVPA) daily are less likely to experience excess body-weight and develop obesity-related chronic diseases.[1, 2] Given that only 6-20% of children in developed countries achieve the recommended 60 minutes of MVPA daily,[3, 4] and that 20-40% are overweight,[5, 6] there is a need for novel interventions that increase physical activity in children.

Schools are considered an ideal setting to deliver interventions that increase physical activity and prevent childhood obesity.[7] The World Health Organization recommends that school-based interventions use a comprehensive approach for health promotion.[8] This approach, known in Canada as Comprehensive School Health (CSH), is multifaceted and involves parents, communities, and stakeholders to provide supportive policies, programs, and environments in the whole school community.[9] In the United States, CSH is referred to as "Coordinated School Health", while the synonymous term "Health Promoting Schools" is used in Australia and Europe.[9] Annapolis Valley Health Promoting Schools (AVHPS)[10] and "Action Schools! BC"[11] are flagship examples of CSH in Canada, and are associated with increased physical activity [10-12] and lower body-weights.[11] In the United States, implementation of CSH or multifaceted approaches significantly increased physical activity levels in school-aged children.[13-16] While school programs have increased physical activity in youth, reviews suggest their effects are modest.[17-20] The Alberta Project Promoting active Living and healthy Eating in Schools (APPLE Schools) builds on and extends previous school-based health promotion interventions by offering the placement of a full-time staff member dedicated to facilitating healthy living programming and curricula.[21, 22]

A key objective of CSH is to foster positive health behaviours beyond the school environment.[9] Most studies to date, however, have quantified the effectiveness of school programs in terms of mean daily physical activity or physical activity accumulated during school time.[10, 11, 13, 21] Very few have extended their observations beyond school hours and none have demonstrated meaningful or significant improvements beyond school hours - a period characterized by low physical activity in youth.[23-28] To determine if the novel APPLE Schools CSH program effectively increased physical activity in children, particularly outside of school, we designed a quasi-experimental trial to test the hypothesis that compared to children receiving standard curriculum, children in schools implementing the APPLE Schools model of CSH would display significantly higher levels of physical activity, particularly outside of school hours.

6.2 Methods

6.2.1 Study design

This was a quasi-experimental pre-post trial with a parallel non-equivalent control group. The APPLE Schools intervention began in January 2008 and lasted through June 2011 and was implemented school-wide. Cross-sectional samples of grade five students were recruited for measurement in the spring each year from 2008 and 2011. This design allowed intervention effects to be assessed over time at the school-level, while controlling for measurement bias. Grade five students were of interest as most are pre-pubescent.[29] Accordingly, boys and girls have similar body compositions,[30, 31] and have not experienced pubertal weight gain[32] or marked declines in physical activity.[12, 33, 34]

The APPLE Schools program targeted schools "in need of health promotion", and therefore elected not to use a clustered randomized controlled design. Separate selection procedures were used to recruit intervention and comparison schools. Schools were considered for the intervention if they were located within socioeconomically disadvantaged neighborhoods and the school principal was willing to support the intervention and research. Based on these criteria, 10 potential schools located in the City of Edmonton and surrounding area were identified. All 10 schools invited agreed to participate. The comparison sample consisted of 20 schools also located in the Edmonton area. Comparison schools were drawn from a sample of randomly selected schools that participated in the 2008 Raising health Eating Active Living Kids Alberta survey.[35] All 20 schools that were invited agreed to participate.

6.2.2 Population

Within each school, all grade five classes and students were invited to participate in the study. Among the 10 APPLE Schools in 2009, home surveys and consent forms were provided to all 412 grade five students for their parents to complete and return to school. A total of 358 parents completed surveys (completion rate=86.9%) and provided their consent for their child to participate. All students with parent consent assented to participate and completed student surveys; 198

of these students also provided complete pedometer recordings and were included in analyses (completion rate=48.1%). In 2011 only 339 youth were enrolled in grade five within APPLE Schools, however the survey completion rates and pedometer data collection were similar (57.8%). In 2009 and 2011, 845 and 680 surveys, respectively were provided to grade five students within the 20 comparison schools. Completion rates of the survey and pedometer data collection were similar in the comparison schools in 2009 (53.7%) and 2011 (45.4%). Comparison schools also had fewer grade five students in 2011 than in 2009.

6.2.3 APPLE Schools intervention

APPLE Schools uses a CSH approach “to make the healthy choice the easy choice”. A key component of the intervention was the placement of a full-time School Health Facilitator in each school. Their role was to facilitate the development and implementation of the project, to ensure that it met the schools’ unique needs for health promotion, and that it aligned with the core principles of CSH. These staff received 6 weeks of extensive training in physical activity, nutrition, creating positive social environments, and facilitations strategies to foster increased capacity and sustainability of the intervention. Stakeholders from each school developed an action plan outlining specific goals, objectives, and actions for the project, which fit within the following four objectives of APPLE Schools to: 1) improve healthy living habits of students; 2) increase knowledge about healthy living for the whole school community; 3) apply and sustain CSH in school communities; and 4) sustain capacity for healthy environments in school communities.[22] Comparison schools did not have access to a School Health Facilitator or the strategies and materials used in APPLE Schools. Though, comparison schools received materials to implement Alberta

Health's provincial Healthy Weights Initiative. This initiative is a public information and education campaign designed to support and encourage Albertans to lead healthier lifestyles.[36] During the study period there was also a provincial policy in place mandating schools to provide a minimum of 30 minutes of daily physical activity to students in grades 1-9.[37]

6.2.4 Outcome of interest: physical activity

Physical activity was determined using the Omron HJ-720ITC time-stamped pedometer (Omron, Toronto Ontario, Canada). The accuracy and validity of the Omron pedometer has been demonstrated under various conditions.[38-41] Students were asked to wear the pedometers for nine consecutive days on the right hip directly in line with the knee during all waking hours unless showering, swimming, or participating in activities that an adult deemed unsafe. Students were also asked to keep a log of daily activities, including the duration and whether or not the pedometer was worn.

6.2.5 Assessment of potential confounders

Students' gender was self-reported. Evaluation assistants measured students' height and body-weight. Height was measured to the nearest 0.1 cm. Body-weight was measured to the nearest 0.1 kg on calibrated digital scales. Body Mass Index (BMI) was calculated as weight divided by height^2 (kg/m^2). Overweight and obesity were defined using the International Obesity Task Force age and sex specific BMI cut-off points.[42] Information on parent educational attainment (secondary school or less; community college; university/graduate school) and household income (≤$50,000; $50,001-$75,000; $75,001-$100,000; >$100,000) were collected from parent responses in the home survey and used as a proxy of socioeconomic status. Class sizes in Alberta follow the Alberta Education recommendation,[43] and therefore were considered to be balanced between groups and not included in modeling procedures.

6.2.6 Statistical analyses

Due to differing administration and collection times, and potential reactivity to the pedometers, step counts from the first and ninth day were not considered in analyses. A valid physical activity data file was defined as a minimum of eight hours of wear-time[44] on a minimum of two school days (Monday-Friday) and one non-school day (weekend and holidays). Pedometer-measured steps were complemented with step equivalents of non-ambulatory and non-wear time activities recorded in activity diaries using established modeling procedures that are described in detail elsewhere.[28]

Students' step-counts were averaged to represent a typical week i.e., five school days and two non-school days. Active-transportation to school was classified as physical activity accumulated 'during school hours' as these activities are characteristic of behaviours on school days and school attendance. Therefore, physical activity occurring during "school hours", was defined as physical activity between 8:00am to 3:59pm and physical activity between 7:00-7:59am and 4:00-8:59pm was defined as "non-school hours". Steps were normalized to hourly-accumulated steps during these periods, by dividing total steps by eight and six hours, respectively. Because others consider active-transport during "non-school hours",[23, 26, 45] we repeated the analyses to include physical activity achieved from 8:00-8:59am and from 3:00-3:59pm as non-school hour physical activity (APPENDIX I). The outcome variables by and large followed a normal distribution.

The normality assumption of the physical activity data was assessed using distributional diagnostic plots and log-transformation. Differences in physical activity levels and participant characteristics from 2009 to 2011 were assessed using t-tests and chi-square tests respectively. To account for the clustering of students' observations within schools, multilevel linear regression methods were used to examine the effect of APPLE Schools on children's physical activity. Specifically, we used mixed models with schools as a random effect. We created an interaction term defined as the product of the binary variables intervention (0=comparison schools, 1=APPLE Schools) and time (0=2009, 1=2011) to assess the effect of APPLE Schools. This term represents the two-year change among students attending APPLE Schools relative to the change among students attending comparison schools. All models included gender, household income, and parental educational attainment to adjust for their confounding potential. For each outcome we also fit a three-way interaction term between the main effect of interest and gender (intervention time x gender) and overweight (intervention x time x overweight). The Intraclass Correlation Coefficient of each outcome was also calculated. STATA version 12 (StataCorp, College Station, TX, USA) was used to perform the statistical analyses. This study, including data collection and informed parental consent forms, was approved by the Health Research Ethics Board at the University of Alberta.

6.3 Results

Characteristics of grade five students within intervention and comparison schools in 2009 and 2011 are presented in Table 1. In 2009, children accumulated 12,311 (3767) and 10,555 (5491) steps/day on school days and non-school days, respectively. Students were on average 10.9 years and 49.5% were girls. Approximately 25% of children came from households of low income or parent education and 33.8% of the entire cohort were overweight or obese. In 2011, the proportion of overweight students was slightly lower (31.9% vs. 33.8% χ^2=0.75, p=0.39), household income (>$100,000: 45.1% vs. 37.5% χ^2=7.26, p=0.007) and parental education were higher (University or graduate school: 34.8% vs 29.2% χ^2=6.25, p=0.012). The distribution of boys and girls was identical in both the intervention and comparison schools. Compared to students that provided valid pedometer data, those that did not were more likely to be boys (44.6% vs. 31.1% χ^2=36.09 P<0.001), and overweight (38.5% vs. 33% χ^2= 4.33 p=0.037). Additionally, the failure to provide valid pedometer data was more common in 2011 compared to 2009 (42.2% vs. 34.9% χ^2= 10.86 p<0.001).

In 2009, students from intervention schools achieved ~2000 (12.9%) fewer steps daily than students from comparison schools (10,707 vs. 12,292 steps/day, p<0.001; Table 1). Differences in physical activity were most evident on non-school days compared to school days. Relative to students from comparison schools, students from intervention schools were also more likely to be overweight (31.3% vs. 38.3%; χ^2=4.7, p=0.03) and to come from households making less than $50,000 annually (18.1% vs. 34.7%; χ^2=23.1, p<0.001).

Daily and hourly step-counts increased between 2009 and 2011 in both intervention and comparison schools, though the increase was less pronounced in children from comparison schools (Table 1). Specifically, during a typical week, physical activity increased by 21.1% in APPLE Schools and by 6.7% in comparison schools. In multilevel analyses, adjusted for gender and socioeconomic status proxies, children with three years of “exposure” to the APPLE Schools intervention (2011) achieved an additional 2152 steps/day on school days (95% CI: 1415, 2888), 2936 steps/day (95% CI: 1802, 4069) on non-school days, and 2341 steps/day (95% CI: 1604, 3079) during a typical week compared to children with only one year of exposure (2009). In adjusted multilevel analyses, three years of exposure to APPLE Schools was associated with greater steps per hour during both school hours (+87 steps/hour; 95% CI: 39; 135) and non-school hours (+239 steps/hour; 95% CI: 153, 324) than those with one year of exposure to the intervention.

A significant interaction was observed between group and time in the adjusted multilevel model, such that children from APPLE Schools experienced increases of 1221 steps/day (95% CI: 306, 2135) on school days, 2001 steps/day (95% CI: 600, 3402) on weekend days, and 1399 steps/day (95% CI: 485, 2312) during a typical week beyond the increases observed on these days among children from comparison schools (Table 2). The intervention effect was also significant when assessing the change in hourly steps outside of school hours between APPLE Schools and comparison schools (β^{**}=137; 95% CI: 31, 242). Exposure to APPLE Schools effectively normalized physical activity levels in the intervention schools relative to those in the comparison schools (Post intervention steps/day during a typical week: APPLE School=12966 vs. comparison school=13120, p=0.67). None of the three-way interaction terms for gender or overweight were statistically significant for any outcome, therefore we are certain that there were no gender-specific or weight-group-specific effects of the intervention.

6.4 Discussion

To our knowledge, this is the first comprehensive study of the effectiveness of CSH on physical activity levels in elementary school children that used full-time, school-based facilitators dedicated to healthy living in each school. The data presented here support observational studies[10] and randomized controlled trials[11, 13, 14, 46] by providing experimental evidence that creating environments that support healthy eating and active living leads to changes in physical activity in children. Furthermore, the data presented here expand on these studies by demonstrating that a more intensive form of CSH elicits significant, clinically relevant increases in physical activity. Finally, and most importantly, the results of this study provide evidence that behaviours learned while "exposed" to CSH extend beyond the school environment and are transferred to non-school days. Collectively, these data provide compelling evidence that the APPLE Schools model of CSH is an effective approach for the promotion of physical activity in youth.

CSH programs that successfully elicited behaviour change in children have included formal curricula[13, 15] or customizable strategies, actions, and resources developed by school-committees based on local needs[10, 11, 14] These programs have been implemented by generalist teachers, expert physical education teachers, or program champions. APPLE Schools extended the concept of a "program champion" by offering the placement of a full-time health facilitator in each school for the duration of the intervention. The "School Health Facilitators" are hired as new school staff members. Their role in the school is dedicated to facilitating the development and implementation of healthy living programming and curricula. Additionally, the project generates annual research reports with school-specific outcomes. These reports provide an opportunity to reflect on achievement of goals and objectives throughout the project and to further tailor the project to meet schools' needs. Finally, the APPLE Schools project developed Professional Learning Communities to provide networking and professional development opportunities for teachers. Similar to other models of CSH,[10, 11, 13, 14, 16, 21] the APPLE Schools program successfully increased physical activity in youth. Importantly, the effect observed with APPLE Schools (~2900 steps/day on weekends) was substantially greater than that seen with other studies. The data presented here reinforce the concept that CSH interventions generally yield positive results compared to those that target single components such as school, family, or community.[47-51] Together the data support the notion that CSH is an effective model for increasing physical activity-related behaviours in youth and extend it by suggesting that this is possible within socioeconomically disadvantaged schools.

Weekends and after-school hours are recognized as "critical windows" for physical activity promotion in youth[52] because they are characterized by low physical activity.[23-28] Previous studies implementing CSH have recognized the need to promote physical activity outside of school hours,[11, 13-16, 53, 54] though few reported stratified findings, and of those that did, increases were negligible or non-significant.[15, 16] The data presented here suggest that including a staff member within the school dedicated to promoting healthy living increases physical activity on school- and non-school days. Importantly, the increased physical activity levels were more pronounced than those on weekdays and during school hours. To foster positive physical activity behaviour during these times, School Health Facilitators regularly informed parents about opportunities for physical activity in their community and coordinated with local providers. Collectively, these data reinforce the key principle of CSH - that coordinated efforts between schools, community stakeholders, and parents are achievable and lead to measurable changes in healthy living behaviours in children.

From the current study, it appears that Alberta Health's Healthy Weights initiative increased physical activity in students from comparison schools. However, because this initiative was implemented in all publically funded schools across Alberta (including intervention schools), it is difficult to quantify its effect given there is no control group to compare outcomes against.

The strengths of the current study include the use of an objective measure of physical activity, a large sample size, adjustments for non-ambulatory and non-wear time activities, measured height and weight, and adjustments for socioeconomic factors. The study has a few limitations, however, that should be acknowledged. First, schools were not randomly selected or assigned to intervention or comparison groups, possibly increasing the risk of selection bias and exaggerating the effect size associated with the intervention. Another potential source of selection bias is the low compliance rate with pedometer wear-time criteria. However rates of non-compliance were similar between comparison and intervention schools therefore, it is unlikely that this influenced the observed effect size. Last, parent responses and student records in activity diaries remain subjective and prone to bias.

6.5 Conclusion

The APPLE Schools program significantly increased physical activity in children, particularly outside of school hours. Accordingly, the data from this study add to the evidence-base for the effectiveness of CSH and provide evidence to support investing in broader implementation of such programs for their potential to prevent obesity and consequent chronic disease.

6.6 References

1. Janssen I, LeBlanc AG. Review Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7 (40):1-16.
2. Stevens J, Murray DM, Baggett CD et al. Objectively assessed associations between physical activity and body composition in middle-school girls: the Trial of Activity for Adolescent Girls. *Am J Epidemiol*. 2007;166 (11):1298-1305.
3. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep*. 2011;22 (1):15-23.
4. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*. 2012;380 (9838):247-257.
5. Shields M. Overweight and obesity among children and youth. *Health Rep*. 2006;17 (3):27-42.
6. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry*. 2012;24 (3):176-188.
7. Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting physical activity in children and youth: a leadership role for schools: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. *Circulation*. 2006;114 (11):1214-1224.
8. Organization WH. The Ottawa Charter for Health Promotion. *Can J Public Health*. 1986;77 425-430.
9. Veugelers PJ, Schwartz ME. Comprehensive school health in Canada. *Can J Public Health*. 2010;101 Suppl 2 S5-S8.
10. Veugelers PJ, Fitzgerald AL. Effectiveness of school programs in preventing childhood obesity: a multilevel comparison. *Am J Public Health*. 2005;95 (3):432-435.
11. Naylor P-J, Macdonald HM, Warburton DER, Reed KE, McKay HA. An active school model to promote physical activity in elementary schools: action

schools! BC. *Br J Sports Med*. 2008;42 (5):338-343.

12. Aaron DJ, Storti KL, Robertson RJ, Kriska AM, LaPorte RE. Longitudinal study of the number and choice of leisure time physical activities from mid to late adolescence: implications for school curricula and community recreation programs. *Arch Pediatr Adolesc Med*. 2002;156 (11):1075-1080.

13. Luepker RV, Perry CL, McKinlay SM et al. Outcomes of a field trial to improve children's dietary patterns and physical activity. *JAMA.* 1996;275 (10):768-776.

14. Pate RR, Ward DS, Saunders RP, Felton G, Dishman RK, Dowda M. Promotion of physical activity among high-school girls: a randomized controlled trial. *Am J Public Health*. 2005;95 (9):1582-1587.

15. Sallis JF, McKenzie TL, Alcaraz JE, Kolody B, Faucette N, Hovell MF. The effects of a 2-year physical education program (SPARK) on physical activity and fitness in elementary school students. Sports, Play and Active Recreation for Kids. *Am J Public Health*. 1997;87 (8):1328-1334.

16. Webber LS, Catellier DJ, Lytle LA et al. Promoting physical activity in middle school girls: Trial of Activity for Adolescent Girls. *Am J Prev Med*. 2008;34 (3):173-184.

17. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. *CMAJ*. 2009;180 (7):719-726.

18. Kamath CC, Vickers KS, Ehrlich A et al. Clinical review: behavioral interventions to prevent childhood obesity: a systematic review and metaanalyses of randomized trials. *J Clin Endocrinol Metab*. 2008;93 (12):4606-4615.

19. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ*. 2012;345 e5888.

20. Sharma M. School-based interventions for childhood and adolescent obesity. *Obes Rev*. 2006;7 (3):261-269.

21. Fung C, Kuhle S, Lu C et al. From" best practice" to" next practice": the effectiveness of school-based health promotion in improving healthy eating and physical activity and preventing childhood obesity. *Int J Behav Nutr Phys Act*. 2012;9 (1):27.

22. Schwartz M, Karunamuni ND, Veugelers PJ. Tailoring and implementing comprehensive school health: The Alberta Project Promoting active Living and healthy Eating in Schools. *Revue phénEPS/PHEnex Journal*. 2010;2 1-15.

23. Belton S, Brady P, Meegan S, Woods C. Pedometer step count and BMI of Irish primary school children aged 6-9 years. *Prev Med*. 2010;50 (4):189-192.

24. Comte M, Hobin E, Majumdar SR, Plotnikoff RC, Ball GD, McGavock J. Patterns of weekday and weekend physical activity in youth in 2 Canadian provinces. *Appl Physiol Nutr Metab*. 2013;38 (2):115-119.

25. Corder K, van Sluijs EM, Ekelund U, Jones AP, Griffin SJ. Changes in children's physical activity over 12 months: longitudinal results from the SPEEDY study. *Pediatrics*. 2010;126 (4):e926-e935.

26. Cox M, Schofield G, Greasley N, Kolt GS. Pedometer steps in primary school-aged children: a comparison of school-based and out-of-school activity. *J Sci Med Sport*. 2006;9 (1-2):91-97.

27. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. *JAMA*. 2008;300 (3):295-305.

28. Vander Ploeg KA, Wu B, McGavock J, Veugelers PJ. Physical activity among Canadian children on school days and nonschool days. *J Phys Act Health*. 2012;9 (8):1138-1145.

29. Arim RG, Shapka JD, Dahinten VS, Willms JD. Patterns and correlates of pubertal development in Canadian youth: effects of family context. *Can J Public Health*. 2007;98 (2):91-96.

30. Guo SS, Chumlea WC, Roche AF, Siervogel RM. Age- and maturity-related changes in body composition during adolescence into adulthood: the Fels Longitudinal Study. *Int J Obes Relat Metab Disord*. 1997;21 (12):1167-1175.

31. Maynard LM, Wisemandle W, Roche AF, Chumlea WC, Guo SS, Siervogel RM. Childhood body composition in relation to body mass index. *Pediatrics*. 2001;107 (2):344-350.

32. Ahmed, ML, Ong KKL, Morrell DJ et al. Longitudinal study of leptin concentrations during puberty: Sex differences and relationship to changes in body composition. *J Clin Endocrinolo & Metabol*. 1998;84 899-905.

33. Brodersen NH, Steptoe A, Boniface DR, Wardle J. Trends in physical activity and sedentary behaviour in adolescence: ethnic and socioeconomic differences. *Br J Sports Med*. 2007;41 (3):140-144.

34. Kimm SY, Glynn NW, Kriska AM et al. Longitudinal changes in physical activity in a biracial cohort during adolescence. *Med Sci Sports Exerc*. 2000;32 (8):1445-1454.

35. Simen-Kapeu A, Veugelers PJ. Should public health interventions aimed at

reducing childhood overweight and obesity be gender-focused? *BMC Public Health*. 2010;10 340.

36. Alberta Health: Healthy Alberta. http://www.healthyalberta.com/
37. Alberta Education Daily Physical Activity Initiative. http://education.alberta.ca/teachers/resources/dpa.aspx
38. Crouter SE, Schneider PL, Karabulut M, Bassett DRJ. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc*. 2003;35 (8):1455-1460.
39. Hasson RE, Haller J, Pober DM, Staudenmayer J, Freedson PS. Validity of the Omron HJ-112 pedometer during treadmill walking. *Med Sci Sports Exerc*. 2009;41 (4):805-809.
40. Holbrook EA, Barreira TV, Kang M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci Sports Exerc*. 2009;41 (3):670-674.
41. Zhu W, Lee M. Invariance of wearing location of Omron-BI pedometers: a validation study. *J Phys Act Health*. 2010;7 (6):706-717.
42. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320 (7244):1240-1243.
43. Alberta Education TC. Establish and implement province-wide guideline for average class size across school jurisdictions. http://education.alberta.ca/department/ipr/archive/commission/report/reality/school/implement.aspx
44. Penpraze V, Reilly JJ, MacLean CM, Montgomery C, Kelly LA. Monitoring of physical activity in young children: how much is enough? *Pediatr Exerc Sci*. 2006;18 (4):483-491.
45. Hardman CA, Horne PJ, Rowlands AV. Children's pedometer-determined physical activity during school-time and leisure-time. *J Exerc Sci Fit*. 2009;7 (2):129-134.
46. Adams MA, Johnson WD, Tudor-Locke C. Steps/day translation of the moderate-to-vigorous physical activity guideline for children and adolescents. *Int J Behav Nutr Phys Act*. 2013;10 49.
47. Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obes Rev*. 2009;10 (1):110-141.

48. Heath GW, Parra DC, Sarmiento OL et al. Evidence-based intervention in physical activity: lessons from around the world. *Lancet*. 2012;380 (9838):272-281.

49. Kriemler S, Meyer U, Martin E, van Sluijs EM, Andersen LB, Martin BW. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *Br J Sports Med*. 2011;45 (11):923-930.

50. Salmon J, Booth ML, Phongsavan P, Murphy N, Timperio A. Promoting physical activity participation among children and adolescents. *Epidemiol Rev*. 2007;29 144-159.

51. Timperio A, Salmon J, Ball K. Evidence-based strategies to promote physical activity among children, adolescents and young adults: review and update. *J Sci Med Sport*. 2004;7 (1 Suppl):20-29.

52. Atkin AJ, Gorely T, Biddle SJ, Marshall SJ, Cameron N. Critical hours: physical activity and sedentary behavior of adolescents after school. *Pediatr Exerc Sci*. 2008;20 (4):446-456.

53. Caballero B, Clay T, Davis SM et al. Pathways: a school-based, randomized controlled trial for the prevention of obesity in American Indian schoolchildren. *Am J Clin Nutr*. 2003;78 (5):1030-1038.

54. Jurg ME, Kremers SP, Candel MJ, Van der Wal MF, De Meij JS. A controlled trial of a school-based environmental intervention to improve physical activity in Dutch children: JUMP-in, kids in motion. *Health Promot Int*. 2006;21 (4):320-330.

6.7 Tables

Table 6.1 Characteristics of grade five students attending APPLE Schools and comparison schools in 2009 and 2011

	APPLE Schools		Comparison Schools	
	2009	2011[*]	2009	2011[*]
Number of schools	10	10	20	20
Number of students	198	196	454	309
Physical Activity (mean (SD))				
School days[†]	11371 (3306)	13375 (3653) [a]	12723 (3885)	13550 (4188) [b]
Non-School days[†]	9048 (5317)	11944 (6,651) [a]	11216 (5441)	12044 (6072) [b]
Typical week[†]	10707 (3331)	12966 (3898) [a]	12292 (3779)	13120 (4127) [b]
School hours[‡]	850 (233)	933 (222) [a]	944 (271)	978 (271) [b]
Non-school hours[‡]	762 (356)	986 (419) [a]	861 (423)	954 (491) [b]
Gender (%)				
Girls	47.2	51.0	50.8	49.1
Boys	52.8	49.0	49.2	50.9
Household Income (%)		[b]		
<50,000	34.7	33.2	18.1	17.8
50,001-100,000	40.0	31.2	37.2	31.8
>100,001	25.3	35.6	44.6	50.4
Parental Education (%)				[b]
Secondary or less	31.9	26.0	27.9	19.8
College	39.1	39.9	42.8	45.1
University/Graduate	29.0	34.1	29.3	35.1
Overweight (%)	38.3	35.2	31.3	30.1

APPLE Schools - Alberta Project Promoting active Living and healthy Eating Schools; SD - standard deviation; Typical week - 5 school days and 2 non-school days (weekend day or holiday)

[*] P-values of differences between 2009 and 2011 derived using chi-square test or t-test where appropriate: see text

[a] P-value <0.001; [b] P-value <0.05; [†] - steps/day; [‡] - steps/hour

Table 6.2 Intervention effect and increases in physical activity between 2009 and 2011 among grade five students attending APPLE Schools and those attending comparison schools.

	Increase in PA in **APPLE Schools**		Increase in PA in **Comparison schools**		**Group x Time Interaction**		**ICC**‡
	β*	95%CI	β*	95%CI	β**	95%CI	
School days (steps/day)	2152	1415, 2888	931	387, 1475	1221	306, 2135	0.037
Non-school days (steps/day)	2936	1802, 4069	935	106, 1764	2001	600, 3402	0.000
Typical week (steps/day)	2341	1604, 3079	943	401, 1485	1399	485, 2312	0.018
School hours (steps/hour)	87	39, 135	40	4, 75	47	-12, 107	0.069
Non-school hours (steps/hour)	239	153, 324	102	39, 165	137	31, 242	0.022

β* represents the increase in physical activity between 2009 and 2011 and was derived from multilevel regression analysis that accommodated clustering of students within schools and adjusted for the confounding potential of gender, parental educational attainment, and household income.

β** represents the intervention effect: the increase in physical activity among students attending APPLE Schools relative to the increase among students attending comparison schools. The estimations accommodated for clustering of students within schools and adjusted for the confounding potential of gender, parental educational attainment, and household income.

‡ Intraclass Correlation Coefficient

7 Do school-based physical activity interventions increase or reduce inequalities in health?

Vander Ploeg KA, Maximova K, McGavock J, Veugelers PJ. Do school-based physical activity interventions increase or reduce inequalities in health? Submitted to Social Science & Medicine Nov, 2013.

7.1 Introduction

Physical activity is associated with improved physical and mental health among children.[1] However, the majority of children do not meet the recommended 60 minutes of daily moderate to vigorous physical activity.[2, 3] Similar to other health outcomes (i.e. obesity, poor diet, smoking), the prevalence of physical inactivity is more common among socioeconomically disadvantaged children.[4-8] This discrepancy in physical activity may contribute to the well-established and robust inequalities in health during both childhood[9, 10] and adulthood.[11, 12] Accordingly, interventions that reduce the inequity in physical activity among socioeconomically disadvantaged children may reduce health inequalities later in life.

Schools are an ideal setting to deliver health promotion programs to children,[13] and various approaches to school-based health promotion have been studied. Programs are deemed successful if the average physical activity level increases. However, the concern has been raised that intervention effects may be more robust among the healthiest children, and less effective among high-risk children.[14, 15] That is, even where school-based health promotion programs are successful at improving physical activity across the population of participating students, they have the potential to create new or perpetuate existing health disparities in the prevalence of physical activity among children.[16, 17] This has been expressed in the literature as the "inequality paradox",[18] or the "inverse care law".[19] Several studies have attempted to overcome this paradox and reduce inequities by implementing programs in schools located in disadvantaged communities,[20-24] while others have used a targeted approach, tailoring interventions to the characteristics of specific groups at risk of poor health behaviours or outcomes.[25-28] Some of these equity-based interventions have reported increases in children's physical activity.[20, 22, 24, 26, 28] However, to our knowledge, no experimental studies exist comparing the effectiveness of a population-based intervention between children in socially disadvantaged and middle income neighbourhoods.

To overcome this limitation and determine if school-based health promotion exacerbate or reduce inequalities in health, the present study compared the two-year change in objectively measured physical activity among low-active, active, and high-active grade five students attending schools with and without health promotion programs. We also compared changes in physical activity among students by body weight status groups and socioeconomic backgrounds to examine whether health promotion is equally effective among those who would benefit the most.

7.2 Methods

7.2.1 Study Design

This was a quasi-experimental pre-post design with a parallel non-equivalent comparison group. The Alberta Project Promoting active Living and healthy Eating in Schools (APPLE Schools) was a school-wide intervention that was launched in January 2008 and lasted through June 2011. Cross-sectional samples of grade five students were recruited for measurement each year in the spring term for the duration of the project. Grade five students were of interest because most are pre-pubescent. Pre-pubescent boys and girls have similar body compositions,[29, 30] and have not experienced pubertal weight gain[31] or marked declines in physical activity.[32-34]

The APPLE Schools intervention targeted schools "in need of health promotion". Accordingly, schools were not randomly assigned to intervention and comparison groups. Schools were considered to become an intervention school if they were located in socioeconomically disadvantaged neighbourhoods and the school principal was willing to support the intervention and research. Based on these criteria, an advisory panel representing five school jurisdictions identified 10 potential schools in the City of Edmonton, Alberta that would benefit from the intervention and therefore qualify for the study. All 10 schools invited elected to participate in the intervention. The comparison schools consisted of a sample of 20 schools also located in Edmonton drawn from a sample of randomly selected schools that participated in the 2008 "Raising health Eating and Active Living Kids" (REAL Kids) Alberta survey.[35] All 20 schools that were invited agreed to participate in the research.

7.2.2 Population

All grade five students within each school were invited to participate in the study. In 2009, among the 10 APPLE Schools, all 412 grade five students were provided with home surveys and consent forms for their parents to complete and return to school. A total of 358 parents completed surveys (completion rate = 86.9%) and provided their consent for their child to participate in the evaluation. All students with parent consent assented to participate and completed student surveys; 198 of these students also provided complete pedometer recordings and were included in analyses (completion rate = 48.1%). In 2011, only 339 students were enrolled in grade five within the APPLE Schools, however, the survey completion rates and the number of complete pedometer recordings were similar (57.8%). In 2009 and 2011, 845 and 680 surveys, respectively were provided to grade five students within the 20 comparison schools. Completion rates of the survey and pedometer recordings were similar in comparison schools in 2009 (53.7%) and 2011 (45.4%). Comparison schools also had fewer grade five students in 2011 than in 2009.

7.2.3 APPLE Schools: the intervention

APPLE Schools uses a Comprehensive School Health (CSH) approach "to make the healthy choice the easy choice". CSH is described as, "an internationally recognized framework for supporting improvements in students' educational outcomes while addressing school health in a planned, integrated, and holistic way".[36] The framework encompasses the whole school environment and addresses actions in four inter-related pillars, including: social and physical environments; teaching and learning; healthy school policy; and partnerships and services.[36] In the United States, CSH is more commonly referred to as "Coordinated School Health", while the synonymous term "Health Promoting Schools" is used in Australia and Europe.[37] A key component of the APPLE Schools CSH intervention was the placement of a full-time School Health Facilitator (SHF) in each school. Their role was to facilitate the development and implementation of the project, to ensure that it met the schools' unique needs for health promotion, and that it aligned with the core principles of CSH. The overall aim of the project was to create and sustain supportive physical and social environments that cultivate a healthy lifestyle with the involvement of key stakeholders i.e., parents, students, staff, and community.

To reach low-active children and those at high risk of inactivity intervention schools offered a variety of non-competitive, enjoyable activity choices like Go-Girls/Go-Boys weekly intramurals, dance, skipping and yoga clubs, walking initiatives, and playground programs. APPLE Schools also had easy and ready-to-use equipment in classrooms to facilitate increased activity in class-time outside of physical education. Steps were also taken to improve access to after-school physical activity facilities and programs, and to improve traffic safety to promote and support active transportation. To reach parents, schools regularly organized school-wide activities where students and parents collectively took part in promotions and events. Monthly school newsletters where also distributed to parents describing affordable, easily accessible, and seasonally appropriate activities for children to participate in outside of school. Comparison schools did not have access to a SHF or the health promotion materials used in APPLE Schools.

7.2.4 Outcome of interest: physical activity

Daily physical activity was measured using the Omron Hj-720ITC time-stamped pedometer (Omron, Toronto Ontario, Canada). The accuracy and validity of the Omron pedometer has been demonstrated under various conditions.[38-41] Evaluation assistants traveled to schools to distribute pedometers and administer a short survey to students. Students were asked to wear their pedometers for nine consecutive days on the right hip directly in line with their right knee during all waking hours unless showering, swimming, or taking part in activities that an adult deemed unsafe. Students were also asked to keep a log of their daily activities, including the duration and whether or not the pedometer was worn. On the third day of data collection, evaluation assistants returned to schools to encourage students to wear the pedometers and to complete their activity diaries. On the ninth day, research staff traveled to schools to collect pedometers and activity diaries, and download data to computers.

7.2.5 Assessment of potential confounders

Students' gender was self-reported in the student survey. Evaluation assistants measured students' standing height and body weight. Height was measured to the nearest 0.1 cm. Body weight was measured to the nearest 0.1 kg on calibrated digital scales. Students removed their shoes for both measurements. Body Mass Index (BMI) was calculated as weight divided by height^2 (kg/m^2). We defined overweight using the International Obesity Task Force BMI cut-off points adjusted to age and sex specific categories for children and youth.[42] Information on household income (≤$50,000; $50,001-$100,000; and >$100,000) and level of parental educational attainment (secondary or less, college, university or above) were determined from parent responses in the home survey.

7.2.6 Statistical Analyses

Pedometer records from the first and ninth days were not considered in data analysis due to differing administration and collection times. A valid physical activity data file was defined as a minimum of eight hours of wear-time[43] on a minimum of two school days and one non-school day. Using the methods we established previously,[44] pedometer steps were complimented with step equivalents of non-ambulatory and non-wear time activities recorded in students' activity diaries. Students' step-counts were averaged to represent a typical week, which was defined as five school days (Monday-Friday) and two non-school days (Saturday, Sunday, holidays).

T-tests and chi-square tests were used to test for differences in physical activity levels and participant characteristics between students attending schools participating in the APPLE Schools intervention and students attending comparison schools in 2009 and 2011. To account for the clustering of students' observations within schools, multilevel linear regression methods were used to examine the effect of the intervention on children's physical activity. We created an interaction term defined as the product of the binary variables year (0 = 2009, 1 = 2011) and intervention (No = comparison schools, Yes = APPLE Schools) to examine the effect of APPLE Schools. This term represents the two-year change among students attending APPLE Schools relative to the change among students attending comparison schools. Students were categorized as low-active, active, and high-active based on step count tertiles according to the evaluation year and intervention status. These categories were also generated for girls and boys separately. Students were also stratified by body weight status, household income, and parental educational attainment. Multilevel analyses were adjusted for potential confounders (see footnote in Table 2). We define "relative inequity" as the difference in the number of steps taken per day between children attending interventions schools and comparison schools. This was calculated from the difference in the adjusted means of the number of steps taken per day in intervention and comparison schools divided by the adjusted mean steps per day in intervention schools. The "change in equity" was defined as the difference in relative inequity from 2009 to 2011. This was calculated by adding the relative difference in 2011 to the absolute value of the relative difference in 2009.

To generate cumulative distribution plots based on students' step-counts, students were stratified according to the evaluation year and intervention status, and where appropriate by overweight status, household income, and parental educational status. Next, students were ranked by step counts and their position in the distribution was plotted against their mean steps per day during a typical week. We used STATA version 12 (StataCorp, College Station TX, USA) to perform the statistical analyses. The Health Research Ethics Board at the University of Alberta approved this study including data collection and informed parental consent forms.

7.3 Results

Characteristics of grade five students within intervention and comparison schools in 2009 and 2011 are presented in Table 1. The average age of students was 10.9 years and 49.5% were girls. The proportion of girls and boys was similar in the intervention and comparison schools. Approximately one quarter and one third of all students came from low-income and low-education households. However the proportion of youth from low-income and low-educated homes was higher in intervention schools than in comparison schools (household income < $50,000: 31.9% vs. 18.0% χ^2=40.08, p<0.001; parental educational attainment < secondary school: 29.2% vs. 24.1% χ^2=5.44, p=0.02 in intervention and comparison schools respectively; Table 1). One third of all students were overweight or obese and, more of these students were from intervention schools (36.9% vs. 31.0% χ^2=8.30, p=0.004).

In 2009, students from intervention schools accumulated approximately 2000 fewer steps per day than students from comparison schools (10827 vs. 12265 steps/day, 95% CI: -2173; -703; Table 2) equating to a 13.3% difference in daily physical activity levels. From 2009 to 2011, physical activity levels increased in both intervention (+2341; p<0.001) and comparison schools (+942; p=0.004).

Daily physical activity level increased 13.0% (effect size = 1399; 95% CI: 485; 2312) more in children from intervention schools than in children from comparison schools. “Exposure” to the APPLE Schools intervention effectively increased physical activity levels of children living in disadvantaged neighbourhoods to the extent that they approximated those of children living “average” neighbourhoods (13168 vs. 13207 steps/day, 95% CI: -830; 751).

In 2009, the proportion of students meeting the recommended levels of daily physical activity was substantially lower in students in the intervention schools compared to comparison schools (Figure 1a). The discrepancy in activity levels between intervention and comparison schools was most pronounced among children classified as low-active, particularly boys (Table 2). Following the 2-year intervention, children within the low-active group from intervention schools experienced an increase in activity 15.3% greater than that of low-active children from comparison schools (effect size = 1124; 95% CI: 522; 1727). This increase in physical activity following the APPLE Schools intervention was greater for children in the low-active group than those in active (+13.3%; effect size = 1391; 95% CI: 1005; 1778) and high-active groups (+12.4%; effect size = 1695; 95% CI: 542; 2848) (Table 2). Daily physical activity increased among children attending APPLE Schools within each physical activity category, however physical activity increased only among children above the ~50th percentile from comparison schools (Figure 1a). This figure also shows that by 2011 steps were approximately equal between the entire distribution of children from APPLE Schools and comparison schools, regardless of baseline physical activity level or socio-economic status.

7.3.1 Sub-group analyses

In 2009, girls from intervention schools were also less active than girls from comparison schools across all activity groups. However, activity levels were most similar between girls from intervention and comparison schools in the low-active group (Table 2). In 2011, daily physical activity levels among girls in the intervention schools exceeded those of girls from comparison schools (Figure 1). In fact "active" girls from the Intervention schools were significantly more active than "active" girls from comparison schools (12155 vs. 11656 steps/day, 95% CI = 174; 824). The largest relative increase among girls was observed among this group.

In 2009, healthy weight and overweight children from intervention schools were 11.1% and 16.8% less active than children of the same body weight status from comparison schools; taking 1241 (95% CI: -2103; -380) and 1716 (95% CI: -2788; -643) fewer steps daily. Following the intervention, activity levels increased among overweight and normal weight children from intervention schools such that they were nearly equal to those among children from comparison schools (normal weight: 13531 vs. 13313, 95% CI: -697; 1132; overweight: 12631 vs. 12807, 95% CI: -1418; 1068). While activity levels increased among both weight status groups, the increase, relative to comparison schools was more pronounced among overweight children from APPLE Schools (Table 2). From 2009 to 2011, all overweight children from intervention schools accumulated more steps daily, while daily step counts increased only among overweight children above the ~40^{th} percentile in comparison schools (Figure 1b). Following the intervention, across the distribution, the mean number of steps taken per day among overweight children from intervention schools and comparison schools were approximately equal (Figure 1b).

Across all income and education groups in 2009, children from intervention schools were less active relative to those from comparison schools. The relative inequity in physical activity levels between intervention groups was greatest between children whose parents were low-educated (i.e., having a secondary school education or less) (-20.7%; 10083 vs. 12168 steps/day; 95% CI: -3398; -772), and least among children from low-income households (-12.7%; 10606 vs. 11952 steps/day; 95% CI: -2984; 292) (Table 2). From 2009 to 2011, children within the low-education and low-income groups from intervention schools experienced increases in physical activity 23.8% (effect size = 2498; 95% CI: 703; 4293) and 23.6% (effect size = 2779; 95% CI: 427; 5131) greater than children within these groups from comparison schools, respectively (Table 2). These increases were more pronounced than those observed among children within the middle (+1.1%; effect size = -37; 95% CI: -1562; 1488) and high (+20.7%; effect size = 2365; 95% CI: 782; 3948) education, and within the middle (+8.8%; effect size = 873; 95% CI: -991; 2738) and high (+13.4%; effect size = 1412; 95% CI: -499; 3323) income groups (Table 2). The increase in daily step counts among the entire distribution of students from low-income and low-education households among APPLE Schools relative to those from comparison schools to evident in Figure 1 c-d.

7.4 Discussion

This study provides compelling evidence that school-based health promotion reduces health inequities among children. First, we showed that after two years of a CSH program, physical activity levels of children living in disadvantaged neighbourhoods increased to the extent that they approximated those of children living “average” neighbourhoods. Second, we showed that the least active children become more active. Third, we showed that overweight and socioeconomically disadvantaged subgroups were evenly, if not favorably, reached.

The concern has been raised that school-based programs may be less effective for high-risk children, particularly among those attending schools in disadvantaged areas.[14, 15] Children living in disadvantages areas are more likely to be physically inactive, be overweight and suffer form chronic disease.[45-50] Environments in socially disadvantaged neighbourhoods often lack access to outdoor playgrounds and recreational facilities, and high crime rates and violence make it unsafe to play outside.[51-53] Several studies have responded to this concern by developing interventions that specifically target children attending schools in these "obeseogenic environments".[20-24, 54] These Programs have been implemented by generalist teachers, experts in physical activity, or program champions, and have included formal curricula and resource packages for teachers, students, and parents, provided equipment and training for classroom teachers, and have made changes to the social and physical environments.[20, 21, 23, 24, 54] The duration of these programs has ranged from 12 weeks[20] to 3 years.[21] Interventions with shorter implementation periods (i.e. 12 or 20 weeks) demonstrated statistically significant increases in physical activity,[20, 54] while those implemented for longer periods did not.[21, 23, 24] Here we demonstrate that the provision of a SHF within the school environment, without any major changes to the built environment, is an efficacious approach for increasing physical activity levels of children living in socially disadvantaged neighbourhoods, and that these increases are stable over time. More importantly, the results presented here extend findings from previous interventions by demonstrating that CSH programs in schools in disadvantaged areas can improve activity levels such that they approximate those of children living in randomly selected "average" neighbourhoods in Alberta, Canada.

Previous studies have demonstrated increases relative to children from equally disadvantaged neighbourhoods, but because of study design limitations, were unable to show that they brought children to the average level.[24, 54] Accordingly, the present study demonstrates that CSH is an efficacious approach to bridge the gap in health inequalities in school-aged children.

Within disadvantaged schools, there remain subgroups of students who are more "in need" of health promotion than others. These groups include students who are low-active and overweight, those whose parents are low-educated, and those from low-income households.[17] Similar to students living in disadvantaged neighbourhoods, students within these groups may be less likely to benefit from health promotion programs than healthier or more advantaged subgroups. Recent systematic reviews have attempted to determine whether school-based health promotion reduces or exacerbates health inequalities, but were unable to do so because few studies report subgroup effects or effects were examined only for specific population subgroups.[16, 55-58] To the best of our knowledge, this is the first experimental study to demonstrate that school-based health promotion can improve physical activity among the entire distribution of students, and reduce health inequalities by improving physical activity levels more favourably amongst the most disadvantaged subgroups. The APPLE Schools CSH program was implemented school-wide and did not specifically target disadvantaged subgroups. To reach the unique needs of each school as well as the various subgroups within schools, each APPLE School formed an "APPLE Core Committee" comprised of the SHF and key stakeholders i.e., students, staff, parents, community partners. The role of the committee was to collaboratively identify goals and develop "Action Plans" to support students in creating and sustaining positive behaviour change. The program also generated annual research reports with school-specific outcomes. These reports provided an opportunity to reflect on achievement of goals and to further tailor the project to meet schools' needs. All "actions" taken in the APPLE Schools to improve students' health were designed to be multifaceted and touch on the four pillars of CSH. The data presented here support the notion that multifaceted interventions generally yield larger effect sizes compared to those that target single components such as policy, built environments, education, or family/community.[14, 15, 59, 60] It is possible that other multifaceted or CSH programs have also reduced inequities, but to show this would require further analysis.

The findings from the present study are also consistent with the idea that "upstream" interventions are more likely to reduce health inequalities than "downstream" interventions.[16, 61, 62] Upstream interventions aim to prevent unhealthy behaviour and promote those that improve health through policy, and changes to the social and physical environments, while downstream interventions focus on individual factors including education. Downstream approaches are said to exacerbate inequalities because they favour people with better social and economic resources and are therefore, better able to benefit from health promotion or interventions.[16, 61] APPLE Schools used a CSH, upstream approach, to create school environments that made "the healthy choice the easy choice".[63] To facilitate increased "uptake" of the intervention in terms of physical activity, all APPLE Schools offered more opportunities for physical activity outside of physical education class, partnered with local recreational facilities to reduce costs and improve access, and created "safe school zones" and "walking school buses" to promote increased active transportation to and from school. The effectiveness of the program as a whole has been shown to improve diet quality and weight loss,[64] and to improve children's activity levels outside of school hours and on weekend days – periods that are characterized by physical inactivity.[65] The demonstrated success of APPLE Schools in improving health behaviours, particularly among the least active children and those from the most disadvantaged circumstances, adds to the evidence-based for the effectiveness of school-based health promotion to improve health outcomes and reduce health inequalities among school-aged children.

Strengths of the current study include the use of an objective measure of children's PA, the large sample size, adjustments for non-ambulatory and non-wear time activities, measured height and weight to assess body weight status, and the ability to adjust for parental educational attainment and household income. However, there are a few limitations of the current study that should be addressed. First, schools were not randomly selected or assigned to an intervention or control condition, possibly increasing the risk of selection bias and exaggerating the effect size associated with the intervention. Another potential source of selection bias were the low compliance rates with pedometer inclusion criteria. These rates, however, were similar among intervention and comparison schools. As such, it is unlikely that this influenced the size of the observed effect. Additionally, when parent and student consent and survey completion rates are considered, the participation rate improved considerably such that they approximated 80-85%. Last, parent responses and student records in activity diaries also remain subjective and prone to bias.

7.5 Conclusion

Our study demonstrated that school health programs in socioeconomically disadvantaged neighborhoods can reduce inequalities in physical activity. Although the school health programs were mostly ecological in nature and did not specifically target student subgroups, they were effective in increasing PA levels relatively evenly among low-active, active and high active students. Likewise they evenly reached normal weight and overweight students and those of distinct socioeconomic background. The health and other benefits that result from the increase in physical activity may contribute to the reduction in inequalities in health. Investments in school based health promotion, therefore, are not only essential to improve PA levels and to prevention of childhood obesity, but they may also reduce health inequalities.

7.6 References

1. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7 40.

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

3. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*. 2012;380 (9838):247-257.

4. Currie C, Molcho M, Boyce W, Holstein B, Torsheim T, Richter M. Researching health inequalities in adolescents: the development of the Health Behaviour in School-Aged Children (HBSC) family affluence scale. *Soc Sci Med*. 2008;66 (6):1429-1436.

5. Ferreira I, van der Horst K, Wendel-Vos W, Kremers S, van Lenthe FJ, Brug J. Environmental correlates of physical activity in youth - a review and update. *Obes Rev*. 2007;8 (2):129-154.

6. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc*. 2000;32 (5):963-975.

7. Seabra AF, Mendonca DM, Thomis MA, Anjos LA, Maia JA. [Biological and socio-cultural determinants of physical activity in adolescents]. *Cad Saude Publica*. 2008;24 (4):721-736.

8. Van Der Horst K, Paw MJ, Twisk JW, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth. *Med Sci Sports Exerc*. 2007;39 (8):1241-1250.

9. Chen E, Martin AD, Matthews KA. Socioeconomic status and health: do gradients differ within childhood and adolescence? *Soc Sci Med*. 2006;62 (9):2161-2170.

10. Marmot M. Social determinants of health inequalities. *Lancet*. 2005;365 (9464):1099-1104.

11. Lynch JW, Kaplan GA, Salonen JT. Why do poor people behave poorly? Variation in adult health behaviours and psychosocial characteristics by stages of the socioeconomic lifecourse. *Soc Sci Med*. 1997;44 (6):809-819.

12. Poulton R, Caspi A, Milne BJ et al. Association between children's

experience of socioeconomic disadvantage and adult health: a life-course study. *Lancet*. 2002;360 (9346):1640-1645.

13. Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting physical activity in children and youth: a leadership role for schools: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. *Circulation*. 2006;114 (11):1214-1224.
14. Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obes Rev*. 2009;10 (1):110-141.
15. Salmon J, Booth ML, Phongsavan P, Murphy N, Timperio A. Promoting physical activity participation among children and adolescents. *Epidemiol Rev*. 2007;29 144-159.
16. Lorenc T, Petticrew M, Welch V, Tugwell P. What types of interventions generate inequalities? Evidence from systematic reviews. *J Epidemiol Community Health*. 2013;67 (2):190-193.
17. Maziak W, Ward KD, Stockton MB. Childhood obesity: are we missing the big picture? *Obes Rev*. 2008;9 (1):35-42.
18. Frohlich KL, Potvin L. Transcending the known in public health practice: the inequality paradox: the population approach and vulnerable populations. *Am J Public Health*. 2008;98 (2):216-221.
19. Hart JT. The inverse care law. *Lancet*. 1971;1 (7696):405-412.
20. Breslin G, Brennan D, Rafferty R, Gallagher AM, Hanna D. The effect of a healthy lifestyle programme on 8-9 year olds from social disadvantage. *Arch Dis Child*. 2012;97 (7):618-624.
21. Caballero B, Clay T, Davis SM et al. Pathways: a school-based, randomized controlled trial for the prevention of obesity in American Indian schoolchildren. *Am J Clin Nutr*. 2003;78 (5):1030-1038.
22. Heath EM, Coleman KJ. Evaluation of the institutionalization of the coordinated approach to child health (CATCH) in a U.S./Mexico border community. *Health Educ Behav*. 2002;29 (4):444-460.
23. Jago R, McMurray RG, Drews KL et al. HEALTHY intervention: fitness, physical activity, and metabolic syndrome results. *Med Sci Sports Exerc*. 2011;43 (8):1513-1522.

24. Jurg ME, Kremers SP, Candel MJ, Van der Wal MF, De Meij JS. A controlled trial of a school-based environmental intervention to improve physical activity in Dutch children: JUMP-in, kids in motion. *Health Promot Int*. 2006;21 (4):320-330.

25. Lubans DR, Morgan PJ, Dewar D et al. The Nutrition and Enjoyable Activity for Teen Girls (NEAT girls) randomized controlled trial for adolescent girls from disadvantaged secondary schools: rationale, study protocol, and baseline results. *BMC Public Health*. 2010;10 652.

26. Pate RR, Ward DS, Saunders RP, Felton G, Dishman RK, Dowda M. Promotion of physical activity among high-school girls: a randomized controlled trial. *Am J Public Health*. 2005;95 (9):1582-1587.

27. Robbins LB, Pfeiffer KA, Vermeesch A et al. "Girls on the Move" intervention protocol for increasing physical activity among low-active underserved urban girls: a group randomized trial. *BMC Public Health*. 2013;13 474.

28. Webber LS, Catellier DJ, Lytle LA et al. Promoting physical activity in middle school girls: Trial of Activity for Adolescent Girls. *Am J Prev Med*. 2008;34 (3):173-184.

29. Guo SS, Chumlea WC, Roche AF, Siervogel RM. Age- and maturity-related changes in body composition during adolescence into adulthood: the Fels Longitudinal Study. *Int J Obes Relat Metab Disord*. 1997;21 (12):1167-1175.

30. Maynard LM, Wisemandle W, Roche AF, Chumlea WC, Guo SS, Siervogel RM. Childhood body composition in relation to body mass index. *Pediatrics*. 2001;107 (2):344-350.

31. Ahmed ML, Ong KKL, Morrell DJ et al. Longitudinal study of leptin concentrations during puberty: sex differences and relationship to changes in body composition. *J Clin Endocrinolo & Metabol*. 1998;84 (3):899-905.

32. Aaron DJ, Storti KL, Robertson RJ, Kriska AM, LaPorte RE. Longitudinal study of the number and choice of leisure time physical activities from mid to late adolescence: implications for school curricula and community recreation programs. *Arch Pediatr Adolesc Med*. 2002;156 (11):1075-1080.

33. Brodersen NH, Steptoe A, Boniface DR, Wardle J. Trends in physical activity and sedentary behaviour in adolescence: ethnic and socioeconomic differences. *Br J Sports Med*. 2007;41 (3):140-144.

34. Kimm SY, Glynn NW, Kriska AM et al. Longitudinal changes in physical activity in a biracial cohort during adolescence. *Med Sci Sports Exerc*. 2000;32 (8):1445-1454.

35. Simen-Kapeu A, Veugelers PJ. Should public health interventions aimed at

reducing childhood overweight and obesity be gender-focused? *BMC Public Health*. 2010;10 340.

36. Joint Consortium for School Health. What is Comprehensive School Health? http://www.jcsh-cces.ca/index.php/school-health

37. Veugelers PJ, Schwartz ME. Comprehensive school health in Canada. *Can J Public Health*. 2010;101 Suppl 2 S5-S8.

38. Crouter SE, Schneider PL, Karabulut M, Bassett DRJ. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc*. 2003;35 (8):1455-1460.

39. Hasson R, Haller J, Pober D, Staudenmayer J, Freedson P. Validity of the Omron HJ-112 pedometer during treadmill walking. *Med Sci Sports Exerc*. 2009;41 (4):805.

40. Holbrook E, Barreira T, Kang M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci Sports Exerc*. 2009;41 (3):670.

41. Zhu W, Lee M. Invariance of wearing location of Omron-BI pedometers: a validation study. *J Phys Act Health*. 2010;7 (6):706.

42. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320 (7244):1240-1243.

43. Penpraze V, Reilly JJ, MacLean CM, Montgomery C, Kelly LA. Monitoring of physical activity in young children: how much is enough? *Pediatr Exerc Sci*. 2006;18 (4):483-491.

44. Vander Ploeg KA, Wu B, McGavock J, Veugelers PJ. Physical activity among Canadian children on school days and nonschool days. *J Phys Act Health*. 2012;9 (8):1138-1145.

45. Achat HM, Stubbs JM. Socio-economic and ethnic differences in the prevalence of overweight and obesity among school children. *J Paediatr Child Health*. 2012

46. Crespo CJ, Smit E, Andersen RE, Carter-Pokras O, Ainsworth BE. Race/ethnicity, social class and their relation to physical inactivity during leisure time: results from the Third National Health and Nutrition Examination Survey, 1988-1994. *Am J Prev Med*. 2000;18 (1):46-53.

47. Gidlow C, Johnston LH, Crone D, Ellis N, James D. A systematic review of the relationship between socio-economic position and physical activity. *Health Edu J*. 2006;65 (4):338-367.

48. Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built environments and

obesity in disadvantaged populations. *Epidemiol Rev*. 2009;31 7-20.

49. Maher CA, Olds TS. Minutes, MET minutes, and METs: unpacking socio-economic gradients in physical activity in adolescents. *J Epidemiol Community Health*. 2011;65 (2):160-165.

50. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry*. 2012;24 (3):176-188.

51. Davidson Z, Simen-Kapeu A, Veugelers PJ. Neighborhood determinants of self-efficacy, physical activity, and body weights among Canadian children. *Health Place*. 2010;16 (3):567-572.

52. Gidlow CJ, Ellis NJ. Neighbourhood green space in deprived urban communities: issues and barriers to use. *Local Environment*. 2011;16 (10):989-1002.

53. Veugelers P, Sithole F, Zhang S, Muhajarine N. Neighborhood characteristics in relation to diet, physical activity and overweight of Canadian children. *Int J Pediatr Obesi*. 2008;3 (3):152-159.

54. Fairclough SJ, Hackett AF, Davies IG et al. Promoting healthy weight in primary school children through physical activity and nutrition education: a pragmatic evaluation of the CHANGE! randomised intervention study. *BMC Public Health*. 2013;13 626.

55. De Bourdeaudhuij I, Simon C, De Meester F et al. Are physical activity interventions equally effective in adolescents of low and high socio-economic status (SES): results from the European Teenage project. *Health Educ Res*. 2011;26 (1):119-130.

56. Humphreys DK, Ogilvie D. Synthesising evidence for equity impacts of population-based physical activity interventions: a pilot study. *Int J Behav Nutr Phys Act*. 2013;10 76.

57. Magnee T, Burdorf A, Brug J et al. Equity-specific effects of 26 Dutch obesity-related lifestyle interventions. *Am J Prev Med*. 2013;44 (6):e57-e66.

58. Yildirim M, van Stralen MM, Chinapaw MJ et al. For whom and under what circumstances do school-based energy balance behavior interventions work? Systematic review on moderators. *Int J Pediatr Obes*. 2011;6 (2-2):e46-e57.

59. Heath GW, Parra DC, Sarmiento OL et al. Evidence-based intervention in physical activity: lessons from around the world. *Lancet*. 2012;380 (9838):272-281.

60. Kriemler S, Meyer U, Martin E, van Sluijs EM, Andersen LB, Martin BW.

Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *Br J Sports Med*. 2011;45 (11):923-930.

61. Orleans CT. Promoting the maintenance of health behavior change: recommendations for the next generation of research and practice. *Health Psychol*. 2000;19 (1 Suppl):76-83.

62. Raine KD. Addressing poor nutrition to promote heart health: moving upstream. *Can J Cardiol*. 2010;26 Suppl C 21C-24C.

63. Schwartz M, Karunamuni ND, Veugelers PJ. Tailoring and implementing comprehensive school health: The Alberta Project Promoting active Living and healthy Eating in Schools. *Revue phénEPS/PHEnex Journal*. 2010;2 (1):1-15.

64. Fung C, Kuhle S, Lu C et al. From “best practice” to “next practice”: the effectiveness of school-based health promotion in improving healthy eating and physical activity and preventing childhood obesity. *Int J Behav Nutr Phys Act*. 2012;9 27.

65. Vander Ploeg KA, McGavock J, Maximova K, PJ V. School-Based Health Promotion and Physical Activity During and After School Hours. *Pediatrics*.

7.7 Tables

Table 7.1 Characteristics of grade 5 students attending APPLE Schools and comparison schools in 2009 and 2011

	2009		2011	
	APPLE Schools*	Comparison schools	APPLE Schools*	Comparison schools
Gender (%)				
Girls	47.2	50.8	51.0	49.1
Boys	52.8	49.2	49.0	50.9
Weight Status		†		
Normal weight	61.7	68.7	64.8	69.9
Overweight/obese (%)	38.3	31.3	35.2	30.1
Household Income (%)		‡		‡
<50,000	34.7	18.1	33.2	17.8
50,001-100,000	40.0	37.2	31.2	31.8
>100,001	25.3	44.6	35.6	50.4
Parental Education (%)				
Secondary or less	31.9	27.9	26.0	19.8
College	39.1	42.8	39.9	45.1
University or graduate	29.0	29.3	34.1	35.1

* APPLE Schools = Alberta Project Promoting active Living and healthy Eating Schools; SD = standard deviation; † = P <0.05; ‡ = P<0.001

Table 7.2 Inequity in physical activity levels (steps/day) by grade five students attending APPLE Schools and comparison schools over a two year interval (2009 to 2011) of a Comprehensive School Health intervention.

	2009				2011				Group x Time effect[§]	95% CI	**Change in equity**[‡]
	APPLE Schools	comparison schools	95% CI	**Relative inequity**[†]	APPLE Schools	comparison schools	95% CI	**Relative inequity**[†]			
Overall[*]	10827	12265	-2173;-703	**-13.3%**	13168	13207	-830;751	**-0.3%**	1399	485; 2312	**+13.0%**
Girls & boys[*]											
Low-active	7366	8508	-1608;-674	**-15.5%**	9096	9113	-517;483	**-0.2%**	1124	522; 1727	**+15.3%**
Active	10489	11897	-1675;-1139	**-13.4%**	12470	12486	-304;273	**-0.1%**	1391	1005; 1778	**+13.3%**
High-active	14345	16509	-3095;-1233	**-15.1%**	17399	17868	-1466;527	**-2.7%**	1695	542; 2848	**+12.4%**
Girls[**]											
Low-active	7424	7874	-962;62	**-6.1%**	9315	8895	-108;947	**+4.5%**	870	139; 1600	**+10.6%**
Active	9911	11100	-1503;-876	**-12.0%**	12155	11656	174;824	**+4.1%**	1689	1238; 2139	**+16.1%**
High-active	13108	15319	-3170;-1252	**-16.9%**	15716	16268	-1583;478	**-3.5%**	1658	329; 2987	**+13.4%**
Boys[**]											
Low-active	7462	9666	-2895;-1513	**-29.5%**	8946	9657	-1481;59	**-7.9%**	1493	498; 2488	**+21.6%**
Active	11492	12836	-1858;-830	**-11.7%**	13351	14125	-1346;-204	**-5.8%**	569	-133; 1272	**+5.9%**
High-active	15655	17659	-3297;-712	**-12.8%**	19178	19472	-1696;1108	**-1.5%**	1710	-88; 3508	**+11.3%**
Weight status[*]											
Normal weight	11159	12400	-2103;-380	**-11.1%**	13531	13313	-697;1132	**-1.6%**	1459	337; 2581	**+12.7%**
Excess weight	10214	11930	-2788;-643	**-16.8%**	12631	12807	-1418;1068	**-1.4%**	1540	-50; 3131	**+15.4%**
Income[***]											
<50,000	10606	11952	-2984;292	**-12.7%**	13165	11732	-597;3463	**+10.9%**	2779	427; 5131	**+23.6%**
50,001-100,000	10782	12112	-2530;-131	**-12.3%**	12985	13442	-1921;1007	**-3.5%**	873	-991; 2738	**+8.8%**
>100,001	10994	12909	-3340;-490	**-17.4%**	12709	13213	-1810;803	**-4.0%**	1412	-499; 3323	**+13.4%**
Education[***]											
≤Secondary	10083	12168	-3398;-772	**-20.7%**	13150	12737	-1125;1951	**+3.1%**	2498	703; 4293	**+23.8%**
College	10999	12212	-2277;-149	**-11.0%**	12590	13840	-2358;-142	**-9.9%**	-37	-1562;1488	**+1.1%**
University	10776	12487	-2955;-468	**-15.9%**	13535	12882	-703;2011	**+4.8%**	2365	782;3948	**+20.7%**

or graduate		

†: ((APPLE Schools – comparison schools)/APPLE Schools)*100

§: represents the interaction of intervention and time: the increase in physical activity among students attending APPLE Schools relative to the increase among students attending comparison schools. The estimations accommodated for clustering of students within schools and are adjusted for potential confounders

‡: |relative difference in 2009| + Relative difference in 2011

*: adjustments for potential confounders included: gender, parental educational attainment, and household income

**: adjustments for potential confounders included: parental educational attainment and household income

***: adjustments for potential confounders included: gender

7.8 Figures

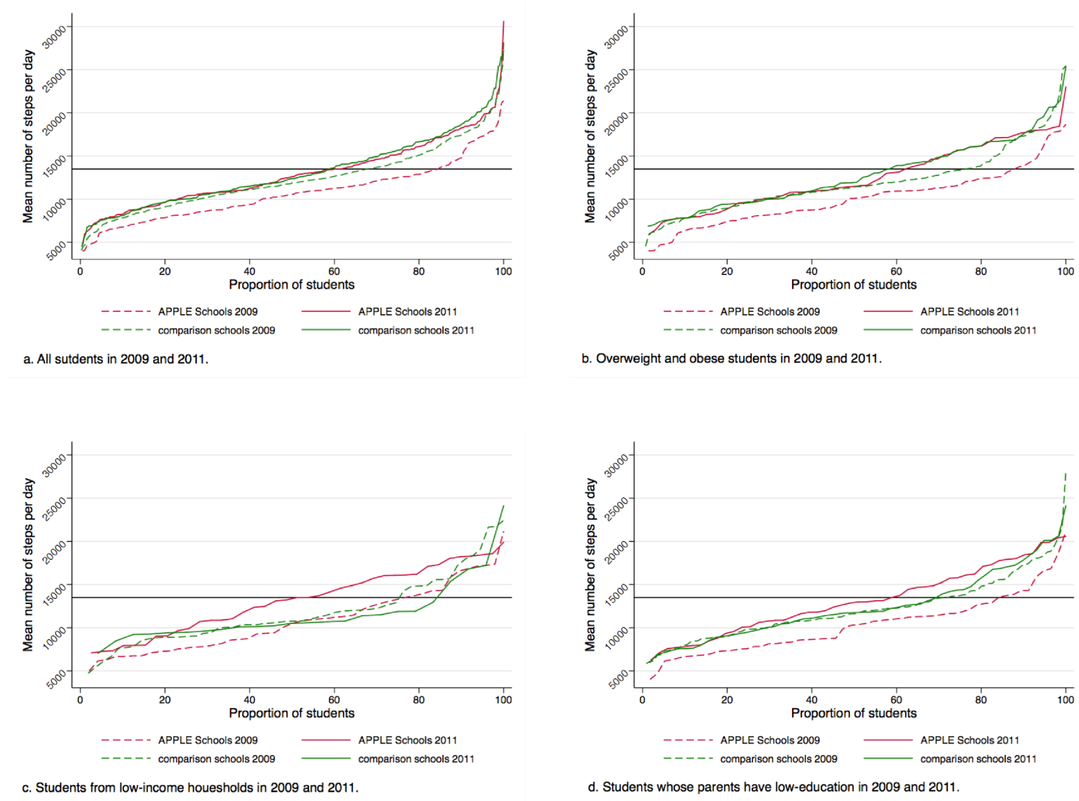

Figure 7.1 Mean number of steps taken per day among a) all students; b) overweight or obese students; c) students from low-income households; d) students whose parents are low-educated from APPLE Schools and comparison schools in 2009 and 2011.

8 General discussion

8.1 Summary of key findings

Establishing healthy habits in childhood is critical for the prevention of obesity and consequent comorbid conditions. Physical activity is one of the most important factors for obesity prevention. While the knowledge-base examining correlates and determinants of physical activity in children is substantial and has been reviewed several times,[1-4] relatively little is known about these factors from a Canadian, particularly Albertan, context. This information is necessary to better inform, develop, and tailor interventions that are effective in preventing increases in obesity among Canadian children.

Schools are considered an ideal setting to deliver interventions that increase physical activity and prevent childhood obesity.[5, 6] Yet to date, most school-based interventions have had limited success.[7-10] Without effective health promotion programing and policies, children's lifetime risk of obesity will continue to rise. Accordingly, there is a strong need for evidence-based research on effective school-based obesity prevention programs.

The first objective of the current thesis was to further our understanding of the levels and patterns of physical activity among children in Alberta, Canada, and the ability of various physical activity measures to identify children at risk of obesity. This objective was assessed in two research papers. We revealed that consideration should be given to activities not captured by pedometers as including non-ambulatory and non-wear time activities may improve the ability to accurately assess children's activity levels, and to identify children who are obese. It was also evident that health-policy decision makers should consider targeting physical activity levels in girls, outside of school hours and on weekends as these variables and windows of time are characterized by low levels of activity.

Building on the conclusions from the first objective, we sought to assess a viable strategy to improve children's physical activity outside of school. Parents, their beliefs and support of physical activity were an appealing choice because children spend the majority of their time in their care. While the literature supports that parents play a significant role in shaping the health behaviours of their children,[11] there are significant gaps in the literature on parenting in regard to physical activity. The second objective, therefore, aimed to fill this gap and determine whether parental beliefs and support of physical activity were associated with children's physical activity outside of school, and with children's body weight status. This objective was accomplished through two interconnected papers using self-reported physical activity data in a population-based sample, and pedometer-measured physical activity data in a smaller sample of children in Alberta, Canada. The conclusions of these studies suggest that health promotion strategies and programs that educate parents on how to effectively support their children in developing healthy physical activity habits may contribute to increases in children's physical activity, particularly on weekend days when activity levels are low, and to preventing overweight among children.

The conclusions of the first two objectives were fed back into the APPLE Schools intervention to improve its effectiveness. This lead to the third objective of the current thesis, which was to assess the ability of school-based health promotion to improve children's physical activity during and beyond school hours, and to determine if school-based health promotion increases or reduces health inequalities. This objective was also examined through two interconnected papers. We found that creating environments that support physical activity leads to positive changes in children's physical activity. Equally important, we shed some light on the mode of action by revealing that behaviours learned and supported while "exposed to CSH" extend beyond the school environment and transfer to weekend days and after school hours. We also found that school health programs in socioeconomically disadvantaged neighbourhoods reduce inequalities in physical activity. And, although the school health programs were mostly ecological in nature and did not specifically target student subgroups, they were effective in increasing physical activity levels relatively evenly among low-active, active, and high active students. Likewise they relatively evenly reached normal weight and overweight students, as well as, those of distinct socioeconomic backgrounds. These studies provide further evidence to support health-policy decision makers to justify investing in broader implementation of effective CSH interventions for physical activity promotion and obesity prevention in the long-term.

The results of this thesis provide researchers and policy decision makers with evidence on current physical activity patterns in children from an Albertan context. They also provide them with evidence to support a potential strategy for physical activity promotion and for the effectiveness of an existing school-based health promotion program. In a culture replete with barriers to physical activity[2, 12-15] and an increasing prevalence of obesity,[16, 17] now more than ever, physical activity policies and promotion programs should be evidence-based and comprehensive in nature to ensure the health of future generations of Canadians.

8.2 Positioning findings in existing literature

In recent years, there has been increasing interest in the use of pedometers to assess physical activity levels in various research settings.[18-24] Pedometers are generally worn at the waist and are most sensitive to vertical accelerations of the hip, which are characteristic of ambulatory activities.[25] A limitation of their use is that they either "miss" or substantially underestimate non-ambulatory activities such as biking, skiing, and skating. Additionally, pedometers are not waterproof and therefore cannot be worn during water-based activities like swimming. Until now, the impact of omitting these and other non-ambulatory activities from children's pedometer-assessed physical activity has largely been unknown. Findings from the current thesis suggest that unadjusted pedometer measured step counts misclassified 31.6% of children as not meeting the 13,500-step/day Canadian physical activity recommendation. This is slightly higher than the amount of misclassification reported in a similar study by Ottevaere et al. of 12-18 year olds.[26] However, the discrepancy in findings likely results from older children's and adolescents' preference for ambulatory activities and younger children's preference for non-ambulatory activities.[27] Further, younger children tend to be less compliant with wear-time recommendations,[28, 29] thereby increasing the amount of misclassification. Regardless of the extent of misclassification, from these studies, it is clear that including additional information derived from activity diaries leads to different interpretations of physical activity levels among young people.

The finding from the current thesis that relative to self-reported physical activity, the association of children's physical activity with obesity is better captured when pedometer-measured step counts incorporate information from students' activity diaries is unique in the literature. Also unique is the conclusion that adjustments made to raw pedometer data for activities they "miss" may reduce the chance of selection bias affecting results. We found that pedometer data from obese children were more likely to be excluded because they did not meet wear-time criteria. This observation is supported in the literature.[26] Overall, the literature would benefit from a "best-practice" method regarding how to adjust pedometer data for these activities, as until now, this has not been explored.

Findings from this thesis revealed that children in Alberta are slightly more active compared to the national average. Specifically, the students sampled in 2009 as part of this thesis took approximately 1000 more steps per day than children from another study using a representative sample of children from Canada.[30] However, only 27% of the students in our sample met the recommended number of steps per day (i.e., 13,500) required to obtain health benefits. Therefore, regardless of how children in Alberta fare in comparison to the Canadian average, they are not sufficiently active.

In this thesis, low physical activity was particularly evident in girls. This finding is highly supported in the literature[1-4, 31, 32] and is believed to result from girls' tendencies to engage in more social activities than boys. [33] Low physical activity was also evident on weekend days. This finding is consistent with some,[19, 31, 34-37] but not others.[38-40] We also observed children to be more active during school than outside of school. Again, there is variability in the literature in regard to activity accumulated during these windows of time; some report higher levels during school[35, 36] and others report higher levels outside of school.[19, 38, 40] It is thought that the variability in physical activity is related to a number of factors that are not well understood i.e., age, culture, involvement in sport.[24] From such inconsistencies in findings reported in the literature, it is clear that additional research is needed to more accurately identify the social and environmental determinants of children's physical activity.

Findings from this thesis are also consistent with reviews and existing literature on physical activity parenting, which indicate that parental beliefs and support for physical activity are positively related to children's physical activity.[41-43] Findings from this thesis advance the literature by demonstrating that parental beliefs and support are positively associated with children's physical activity achieved on weekend days, and negatively associated with childhood overweight. In the present thesis, encouragement of physical activity was consistently one of the most important parenting practices for children's physical activity. Other studies report similar findings.[44, 45] It is believed that encouragement is mediated through psychosocial attributes including improved self-efficacy and liking of and attraction to physical activity.[44, 46]

The findings presented here demonstrating that increases in children's physical activity can be achieved by creating environments supportive of active living are supported in the literature.[47-51] However, reviews and meta-analyses suggest that the effects of physical activity interventions, which are ecological in nature, are generally modest.[7-10] The increases in physical activity attributable to the APPLE Schools CSH program therefore advance the literature, as they were both statistically significant and clinically meaningful.

The suggestion to promote physical activity outside of school hours and on weekends is recognized in the literature,[47-49, 51-54] yet few school-based interventions have reported outcomes specific to these windows of time. While the results presented here support the directionality of the findings of those that did,[51, 54] their magnitude is unique. Until now, findings reported in the literature on improving physical activity outside of school through school-based health promotion have been negligible or non-significant.[51, 54] More importantly, the increases in physical activity we reported were more pronounced on weekend days and the hours outside of school than those during school and on weekdays. These findings are novel and thereby establish the APPLE Schools CSH approach as a promising strategy for physical activity promotion and obesity prevention.

Additionally, findings from this thesis confirm those of other studies that health promotion programs can effectively increase physical activity among children from disadvantaged backgrounds.[55, 56] Furthermore, and more importantly, they extend them by demonstrating that CSH approaches implemented in schools located in disadvantaged neighbourhoods lead to improvements in children's physical activity levels who would be considered "in need" of health promotion such that they approximate those of children living in more advantaged areas. This finding is novel and important because this discrepancy contributes to clear and robust inequalities in health during childhood[57] and adulthood.[58]

Within schools located in socioeconomically disadvantaged neighbourhoods there remain subgroups of students who are more "in need" of health promotion than others.[59] These groups include students who are low-active and overweight, those whose parents are not highly educated, and those who are from low-income households. No previous studies had assessed the distribution of program effects among children of differing levels of activity, health, and socioeconomic backgrounds. Accordingly, the findings from this thesis suggesting that all students can receive health benefits from CSH programs, and that these benefits are relatively evenly distributed among high- and low-need students is novel. These important findings suggest that CSH may contribute to reductions in inequalities in health.

8.3 Methodological considerations

Existing studies have identified several challenges surrounding the measurement of physical activity and statistical analysis of epidemiological data.[60-64] Accurate measures of physical activity are required to assess levels and patterns of physical activity and the relationship of physical activity with various factors, and to determine the effectiveness of physical activity intervention programs.[63] Accordingly, measurement techniques used for research and program evaluation must be valid, practical, reliable, and non-reactive. These properties were considered when selecting the monitoring device and developing the data collection and management protocols used in the current thesis. Specifically, we chose the Omron HJ-720ITC pedometer because it had been previously validated.[65-67] This pedometer was a practical choice because of its relatively low cost (i.e. $40/device), as well as, its ability to record hourly steps, store data for 42 days, and automatically reset at midnight, thereby eliminating the need for students to record their steps at the end of the day. To ensure the reliability of the physical activity estimates reported in this thesis, a complete day was considered as 8 or more hours of wear-time,[68] on at least two school days and one non-school day i.e., weekend days or holidays.[18] Further, outlying observations were identified using cut-points of below 1,000 steps/day and above 30,000 steps/day[19] and subsequently deleted and treated as missing data. To reduce the likelihood of physical activity estimates being influenced by reactivity, pedometer records from the first and last day were not considered in the analysis of data.[69]

Potential sources of error were also considered when developing and executing the protocol for the statistical analyses used in this thesis. First, missing data were considered. Relative to adults, children tend to be less compliant of pedometer wear time criteria.[28, 29] Therefore when students forgot to wear their pedometer and complete their activity log, steps from other randomly selected complete days were imputed. Imputations were only carried out within an individual, within school days and within weekend days. This method of imputation replaces data more accurately than traditional group-centered methods that replace missing data with the group mean.[70]

Second, in all studies, students were clustered within schools. Accordingly, some correlation between students within schools was expected. Therefore, the variances within and between schools were considered through random effects modeling procedures with schools as the random effect. In the case of studies five and six, modeling procedures were expanded to address the hierarchical structure of the data by introducing a variable that indicated the schools' intervention status at a level above those representing individual student observations i.e., physical activity, gender, parental educational attainment, household income, year.

Third, all analyses were adjusted for factors that could potentially confound the relationship between exposure and outcome variables. Potential confounders were selected a priori based on knowledge of the subject matter from previous studies. These included gender,[1-4, 32] and parental educational attainment and household income as proxies of socioeconomic status.[3, 13, 32, 71] Age[1-4, 32] was not considered because all children participating were between 10 and 11 years old. Children's BMI (or body weight status) was not considered because it lies on the causal pathway, downstream of physical activity.[72] There is the potential of residual confounding in studies three through six if confounding variables exists, but remain unidentified or if variables were not measured accurately.[61] This potential source of error could have been eliminated if schools were randomized to intervention and control groups in studies five and six as this process balances all known and unknown confounders between groups.[61] However, APPLE Schools is committed to supporting those schools most in need of health promotion, and as such, randomization would have been inappropriate.[73]

Last, effect modifiers were also considered in the analysis of data. If suspected, stratified analyses were conducted or interaction terms were added to statistical models and results were interpreted separately. There were no statistically significant effect modifiers in any of the studies in the current thesis.

8.4 Strengths and limitations

One of the major strengths of the current thesis is the use of an objective measure of physical activity for five of the six manuscripts. In pediatric populations, objective measures are generally preferred over subjective measures such as self-report because children's cognitive capacity and sporadic behaviour make it particularly challenging for them to accurately recall, categorize, and record activities.[74, 75] Objective measures of physical activity may be logistically and financially challenging in large population-based studies, as was the case in the third manuscript, which was the only study in this thesis to use a self-reported outcome. While self-reported measures are prone to bias and may produce an overestimation of children's physical activity,[76] this study used a validated self-reported questionnaire,[77, 78] thereby substantiating the accuracy of our findings. Other strengths of this thesis include the following: the use of both observational (Objective 1 and 2) and experimental (Objective 3) epidemiological study designs; the use of complex statistical approaches including multi-level random effects models, linear and logistic regression, Receiver Operating Characteristics and Area Under the Curve analyses, weighting, adjusting for potential confounders; the development of a novel approach to deal with missing data and energy expenditure not captured by pedometers; the high response rate for school-based research;[79] measured BMI; multiple years of observation; and large sample size.

A few limitations of the current thesis should be acknowledged. The first relates to the cross-sectional nature of studies three and four, and necessitates caution with respect to interpretations of directionality and causality of the associations between parental beliefs and support variables and children's physical activity. An additional limitation is that self-reported responses to questions surrounding children's physical activity, parental beliefs and support, and socioeconomic status are prone to bias and may produce socially desirable responses. Accordingly, for the studies that used categorical or binary variables or outcomes, there may exist some non-differential misclassification.[61] For example, in the studies assessing physical activity parenting (Objective 2), misclassification bias may have underestimated the actual effect on children's physical activity and weight status.[61] Also, although analyses were adjusted for all known potential confounders, it is possible that some were missed. As such, it is possible that residual confounding may have prevented the true relationship of the exposures and outcomes of interest in all objectives from being observed.[61] Further, although the schools that participated in pedometer research were selected from a population-based sample, the samples of students and parents in studies one, two, and four are not representative of the Alberta population. Caution is therefore warranted when generalizing these results.

There are a few limitations specific to studies five and six that should also be mentioned. First is the lack of a baseline *objective* measure of children's physical activity. As such, the results presented in this thesis provide a conservative estimate of the effectiveness of the APPLE Schools intervention in improving children's physical activity. Second, the schools were not randomly selected or assigned to intervention or control groups. Therefore, the generalizability of the results may be limited.

8.5 Public health implications

Results from the current thesis have a number of important implications for public health. Findings indicate that immediate policy action is necessary to increase physical activity levels among Canadian children. Given its modifiable nature, physical activity is an ideal target for public health interventions. Large-scale, population-based physical activity interventions have been successful in effecting change.[80] However, results from this thesis indicate that policy makers should consider targeting girls, overweight children, and those from socioeconomically disadvantaged backgrounds. These subgroups of children are characterized by low levels of physical activity and previous research has raised the concern that "one-size-fits-all" interventions may offer little benefit to those most in need of health promotion.[59, 81, 82] Findings of this thesis also indicate that policy makers should consider extending health promotion strategies to after school hours and weekends as activity levels are substantially lower during these windows of time than during school hours and on school days, respectively.

Two important opportunities for health promotion targeting these groups and times are supported by the results of this thesis. The first involves educating parents on how to effectively support their children in developing a healthy active lifestyle. The second involves investing in widespread implementation of intensive CSH programs for their potential to increase physical activity, prevent obesity, and reduce health inequalities. Researchers and policy makers developing and investing in widespread implementation of interventions to promote physical activity may want to consider tailoring strategies to target these groups and time correlates.

8.6 Recommendations for future research

The present work identifies several areas that require future research. First, validation studies are needed to assess the accuracy of methods used to adjust pedometer-measured steps so that physical activity outcomes reflect children's actual activity levels. These studies would ensure that researchers are using the best available methods to measure constructs of energy expenditure. Further they would ensure a unified approach to the assessment and classification of children meeting physical activity recommendations, thereby enhancing the comparability of data.

Second, more observational studies are needed to identify key determinants of children's behaviour after school hours and on weekends. Understanding the factors that influence children's physical activity during these windows of time can support intervention and policy development.

Third, the relationship between physical activity parenting and children's health outcomes should be further assessed. Specifically, more observational studies are needed to identify additional dimensions of physical activity parenting as the literature on this field of research is less ample than that of other parenting practices.[11] New methods are also needed to reduce the likely socially desirable responses to existing questions on parenting behaviours. Future studies should also focus on the longitudinal relationship between parental influences and children's physical activity. These studies would provide further insight into the direction of the relationship as well as provide support for intervention studies to assess whether improving parenting practices improves children's physical activity and reduces overweight. Further investigation of this relationship is needed to provide additional high quality data to influence policy and support intervention programs.

Fourth, rigorous evaluations of CSH are urgently needed to establish the long-term health outcomes and benefits of CSH programs. These studies would better guide public health decision makers in directing resources towards broader implementation of school-based interventions. Future evaluation of CSH programs should consider designing studies with longer follow-up periods and a larger number of schools.

Finally, economic analyses are also needed to establish the cost-effectiveness of CSH for disease prevention. The negative health consequences of obesity place a substantial economic burden on the health care system and society.[83, 84] Such studies would likely justify devoting more classroom time and resources to CSH programs to support healthy eating and activity living behaviours.

8.7 References

1. Alberga AS, Sigal RJ, Goldfield G, Prud'homme D, Kenny GP. Overweight and obese teenagers: why is adolescence a critical period? *Pediatr Obes*. 2012;7 (4):261-273.
2. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet*. 2012;380 (9838):258-271.
3. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc*. 2000;32 (5):963-975.
4. Uijtdewilligen L, Nauta J, Singh AS et al. Determinants of physical activity and sedentary behaviour in young people: a review and quality synthesis of prospective studies. *Br J Sports Med*. 2011;45 (11):896-905.
5. Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting physical activity in children and youth: a leadership role for schools: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. *Circulation*. 2006;114 (11):1214-1224.
6. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry*. 2012;24 (3):176-188.
7. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. *CMAJ*. 2009;180 (7):719-726.
8. Kamath CC, Vickers KS, Ehrlich A et al. Clinical review: behavioral interventions to prevent childhood obesity: a systematic review and metaanalyses of randomized trials. *J Clin Endocrinol Metab*. 2008;93 (12):4606-4615.
9. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ*. 2012;345 e5888.
10. Sharma M. School-based interventions for childhood and adolescent obesity. *Obes Rev*. 2006;7 (3):261-269.
11. Baranowski T, O'Connor T, Hughes S et al. Houston. We have a problem! Measurement of parenting. *Child Obes*. 2013;9 Suppl S1-S4.

12. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth a review. *Am J Prev Med*. 2011;41 (4):442-455.

13. Ferreira I, van der Horst K, Wendel-Vos W, Kremers S, van Lenthe FJ, Brug J. Environmental correlates of physical activity in youth - a review and update. *Obes Rev*. 2007;8 (2):129-154.

14. Hill JO, Peters JC. Environmental contributions to the obesity epidemic. *Science*. 1998;280 (5368):1371-1374.

15. Hill JO, Wyatt HR, Reed GW, Peters JC. Obesity and the environment: where do we go from here? *Science*. 2003;299 (5608):853-855.

16. Canada S, Burwinkle TM, Varni JW. Canadian Health Measures Survey: Body composition and fitness.

17. Tremblay MS, Shields M, Laviolette M, Craig CL, Janssen I, Connor Gorber S. Fitness of Canadian children and youth: results from the 2007-2009 Canadian Health Measures Survey. *Health Rep*. 2010;21 (1):7-20.

18. Craig CL, Tudor-Locke C, Cragg S, Cameron C. Process and treatment of pedometer data collection for youth: the Canadian Physical Activity Levels among Youth study. *Med Sci Sports Exerc*. 2010;42 (3):430-435.

19. Rowe DA, Mahar MT, Raedeke TD, Lore J. Measuring physical activity in children with pedometers: Reliability, reactivity, and replacement of missing data. *Pediatr Exerc Sci*. 2004;16 (4):343-354.

20. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity: convergent validity. *Sports Med*. 2002;32 (12):795-808.

21. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity: construct validity. *Sports Med*. 2004;34 (5):281-291.

22. Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-determined steps per day in US children and youth. *Med Sci Sports Exerc*. 2010;42 (12):2244-2250.

23. Tudor-Locke C, Craig CL, Beets MW et al. How many steps/day are enough? for children and adolescents. *Int J Behav Nutr Phys Act*. 2011;8 78.

24. Tudor-Locke C, McClain JJ, Hart TL, Sisson SB, Washington TL. Expected values for pedometer-determined physical activity in youth. *Res Q Exerc Sport*. 2009;80 (2):164-174.

25. Graser SV, Pangrazi RP, Vincent WJ. Effects of placement, attachment, and weight classification on pedometer accuracy. *J Phys Act Health*. 2007;4

(4):359-369.

26. Ottevaere C, Huybrechts I, De Meester F, De Bourdeaudhuij I, Cuenca-Garcia M, De Henauw S. The use of accelerometry in adolescents and its implementation with non-wear time activity diaries in free-living conditions. *J Sports Sci*. 2011;29 (1):103-113.

27. Institute CFLR, Armstrong TP, Xuereb GC. Bulletin 7: Children's participation in sport. 2010

28. Colley R, Connor Gorber S, Tremblay MS. Quality control and data reduction procedures for accelerometry-derived measures of physical activity. *Health Rep*. 2010;21 (1):63-69.

29. Tudor-Locke C, McClain JJ, Hart TL, Sisson SB, Washington TL. Pedometry methods for assessing free-living youth. *Res Q Exerc Sport*. 2009;80 (2):175-184.

30. Craig CL, Cameron C, Tudor-Locke C. CANPLAY pedometer normative reference data for 21,271 children and 12,956 adolescents. *Med Sci Sports Exerc*. 2013;45 (1):123-129.

31. Comte M, Hobin E, Majumdar SR, Plotnikoff RC, Ball GD, McGavock J. Patterns of weekday and weekend physical activity in youth in 2 Canadian provinces. *Appl Physiol Nutr Metab*. 2013;38 (2):115-119.

32. Van Der Horst K, Paw MJ, Twisk JW, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth. *Med Sci Sports Exerc*. 2007;39 (8):1241-1250.

33. Blatchford P, Baines E, Pellegrini A. The social context of school playground games: Sex and ethnic differences, and changes over time after entry to junior school. *Br J Dev Psychol*. 2003;21 (4):481-505.

34. Duncan MJ, Al-Nakeeb Y, Woodfield L, Lyons M. Pedometer determined physical activity levels in primary school children from central England. *Prev Med*. 2007;44 (5):416-420.

35. McGall SE, McGuigan MR, Nottle C. Contribution of free play towards physical activity guidelines for New Zealand primary school children aged 7-9 years. *Br J Sports Med*. 2011;45 (2):120-124.

36. Nyberg GA, Nordenfelt AM, Ekelund U, Marcus C. Physical activity patterns measured by accelerometry in 6- to 10-yr-old children. *Med Sci Sports Exerc*. 2009;41 (10):1842-1848.

37. Rowlands AV, Pilgrim EL, Eston RG. Patterns of habitual activity across weekdays and weekend days in 9-11-year-old children. *Prev Med*. 2008;46 (4):317-324.

38. Belton S, Brady P, Meegan S, Woods C. Pedometer step count and BMI of Irish primary school children aged 6-9 years. *Prev Med*. 2010;50 (4):189-192.

39. Cox M, Schofield G, Greasley N, Kolt GS. Pedometer steps in primary school-aged children: a comparison of school-based and out-of-school activity. *J Sci Med Sport*. 2006;9 (1-2):91-97.

40. Hardman CA, Horne PJ, Rowlands A. Children's pedometer-determined physical activity during school-time and leisure-time. *J Exerc Sci Fit*. 2009;7 (2):129-134.

41. Edwardson CL, Gorely T. Parental influences on different types and intensities of physical activity in youth: A systematic review. *Psycholo Sport Exerc*. 2010;11 (6):522-535.

42. Pugliese J, Tinsley B. Parental socialization of child and adolescent physical activity: a meta-analysis. *J Fam Psychol*. 2007;21 (3):331-343.

43. Trost SG, Loprinzi PD. Parental influences on physical activity behavior in children and adolescents: A brief review. *Am J Lifestyle Med*. 2011;5 (2):171-181.

44. Brustad RJ. Who Will Go Out and Play? Parental and psychological influences on children's attraction to physical activity. *Pediatr Exerc Sci*. 1993;5 210-223.

45. McGuire MT, Hannan PJ, Neumark-Sztainer D, Cossrow NH, Story M. Parental correlates of physical activity in a racially/ethnically diverse adolescent sample. *J Adolesc Health*. 2002;30 (4):253-261.

46. Brustad RJ. Attraction to physical activity in urban schoolchildren: parental socialization and gender influences. *Res Q Exerc Sport*. 1996;67 (3):316-323.

47. Luepker RV, Perry CL, McKinlay SM et al. Outcomes of a field trial to improve children's dietary patterns and physical activity. The Child and Adolescent Trial for Cardiovascular Health. CATCH collaborative group. *JAMA*. 1996;275 (10):768-776.

48. Naylor PJ, Macdonald HM, Warburton DE, Reed KE, McKay HA. An active school model to promote physical activity in elementary schools: action schools! BC. *Br J Sports Med*. 2008;42 (5):338-343.

49. Pate RR, Ward DS, Saunders RP, Felton G, Dishman RK, Dowda M. Promotion of physical activity among high-school girls: a randomized controlled trial. *Am J Public Health*. 2005;95 (9):1582-1587.

50. Veugelers PJ, Fitzgerald AL. Effectiveness of school programs in preventing childhood obesity: a multilevel comparison. *Am J Public Health*. 2005;95

(3):432-435.

51. Webber LS, Catellier DJ, Lytle LA et al. Promoting physical activity in middle school girls: Trial of Activity for Adolescent Girls. *Am J Prev Med*. 2008;34 (3):173-184.

52. Caballero B, Clay T, Davis SM et al. Pathways: a school-based, randomized controlled trial for the prevention of obesity in American Indian schoolchildren. *Am J Clin Nutr*. 2003;78 (5):1030-1038.

53. Jurg ME, Kremers SP, Candel MJ, Van der Wal MF, De Meij JS. A controlled trial of a school-based environmental intervention to improve physical activity in Dutch children: JUMP-in, kids in motion. *Health Promot Int*. 2006;21 (4):320-330.

54. Sallis JF, McKenzie TL, Kolody B, Lewis M, Marshall S, Rosengard P. Effects of health-related physical education on academic achievement: project SPARK. *Res Q Exerc Sport*. 1999;70 (2):127-134.

55. Breslin G, Brennan D, Rafferty R, Gallagher AM, Hanna D. The effect of a healthy lifestyle programme on 8-9 year olds from social disadvantage. *Arch Dis Child*. 2012;97 (7):618-624.

56. Fairclough SJ, Hackett AF, Davies IG et al. Promoting healthy weight in primary school children through physical activity and nutrition education: a pragmatic evaluation of the CHANGE! randomised intervention study. *BMC Public Health*. 2013;13 626.

57. Marmot M. Social determinants of health inequalities. *Lancet*. 2005;365 (9464):1099-1104.

58. Poulton R, Caspi A, Milne BJ et al. Association between children's experience of socioeconomic disadvantage and adult health: a life-course study. *Lancet*. 2002;360 (9346):1640-1645.

59. Frohlich KL, Potvin L. Transcending the known in public health practice: the inequality paradox: the population approach and vulnerable populations. *Am J Public Health*. 2008;98 (2):216-221.

60. Hill AB. The environment and disease: association or causation? *Proceedings of the Royal Society of Medicine*. 1965;58 (5):295.

61. Rothman KJ, Greenland S, Professor TLLA. *Modern Epidemiology*. ThirdLippincott Williams & Wilkins; 2008.

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

63. Wareham NJ, Rennie KL. The assessment of physical activity in individuals and populations: why try to be more precise about how physical activity is

assessed? *Int J Obes Relat Metab Disord*. 1998;22 Suppl 2 S30-S38.

64. Westerterp KR. Assessment of physical activity: a critical appraisal. *Eur J Appl Physiol*. 2009;105 (6):823-828.

65. Hasson R, Haller J, Pober D, Staudenmayer J, Freedson P. Validity of the Omron HJ-112 pedometer during treadmill walking. *Med Sci Sports Exerc*. 2009;41 (4):805.

66. Holbrook E, Barreira T, Kang M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci Sports Exerc*. 2009;41 (3):670.

67. Zhu W, Lee M. Invariance of wearing location of Omron-BI pedometers: a validation study. *J Phys Act Health*. 2010;7 (6):706.

68. Penpraze V, Reilly JJ, MacLean CM, Montgomery C, Kelly LA. Monitoring of physical activity in young children: how much is enough? *Pediatr Exerc Sci*. 2006;18 (4):483-491.

69. Vincent SD, Pangrazi RP. Does reactivity exist in children when measuring activity levels with pedometers?/La reactivite existe-t-elle chez des enfants lorsque que l\’on mesure leur niveau d\’activite al\’aide d\’un podometre? *Pediatr Exerc Sci*. 2002;14 (1):56-63.

70. Kang M, Zhu W, Tudor-Locke C, Ainsworth BE. An experimental determination of the best missing-value recovery method in assessing physical activity using pedometers. *Res Q Exerc Sport*. 2003;74 (1

71. Seabra AF, Mendonca DM, Thomis MA, Anjos LA, Maia JA. [Biological and socio-cultural determinants of physical activity in adolescents]. *Cad Saude Publica*. 2008;24 (4):721-736.

72. Dietz WH, Gortmaker SL. Preventing obesity in children and adolescents. *Annu Rev Public Health*. 2001;22 337-353.

73. Murray DM, Pennell M, Rhoda D, Hade EM, Paskett ED. Designing studies that would address the multilayered nature of health care. *J Natl Cancer Inst Monogr*. 2010;2010 (40):90-96.

74. Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and tempo of children’s physical activities: an observational study. *Med Sci Sports Exerc*. 1995;27 (7):1033-1041.

75. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. *Res Q Exerc Sport*. 2000;71 (2 Suppl):S1-14.

76. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports*

Exerc. 2008;40 (1):181-188.

77. Crocker PR, Bailey DA, Faulkner RA, Kowalski KC, McGrath R. Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. *Med Sci Sports Exerc*. 1997;29 (10):1344-1349.

78. Kowalski KC, Crocker PRE, RA. F. Validation of the Physical Activity Questionnaire for Older Children. *Pediatr Exerc Sci*. 1997;9 174-186.

79. Finn-Aage E, Melde C, Taylor TJ, Peterson D. Active parental consent in school-based research: how much is enough and how do we get it. *Eval Rev*. 2008;32 (4):335-362.

80. Craig CL, Bauman A, Gauvin L, Robertson J, Murumets K. ParticipACTION: A mass media campaign targeting parents of inactive children; knowledge, saliency, and trialing behaviours. *Int J Behav Nutr Phys Act*. 2009;6 88.

81. Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obes Rev*. 2009;10 (1):110-141.

82. Salmon J, Booth ML, Phongsavan P, Murphy N, Timperio A. Promoting physical activity participation among children and adolescents. *Epidemiol Rev*. 2007;29 144-159.

83. Tran BX, Nair AV, Kuhle S, Ohinmaa A, Veugelers PJ. Cost analyses of obesity in Canada: scope, quality, and implications. *Cost Eff Resour Alloc*. 2013;11 (1):3.

84. Trasande L, Elbel B. The economic burden placed on healthcare systems by childhood obesity. *Expert Rev Pharmacoecon Outcomes Res*. 2012;12 (1):39-45.

9 Appendix

9.1 Appendix I

Intervention effect and increases in physical activity during† and beyond‡ school hours, and active transportation between 2009 and 2011 among grade five students attending APPLE Schools and those attending comparison schools.

	Increase in PA in **APPLE Schools**		Increase in PA in **Comparison schools**		**Group x Time Interaction**		**ICC**§
	β*	95%CI	β*	95%CI	β**	95%CI	
School hours (steps/hour)	91	43, 139	79	43,115	11	-48, 71	0.158
Non-school hours (steps/hour)	176	106, 246	54	3,106	121	35, 208	0.033
Active Transportation							
To & from school	117	-81, 315	-266	-414,-117	383	136,629	0.133
To school***	84	-24, 192	-130	-211,-49	214	79, 348	0.179
From school****	33	-99, 164	-136	-234,-38	169	5, 332	0.110

† during school hours was defined as the hours between 9:00am and 2:59pm

‡ beyond school hours was defined as the hours of 7:00am to 8:59 am and 3:00 to 8:59pm

β* represents the increase in physical activity between 2009 and 2011 and was derived from multilevel regression analysis that accommodated clustering of students within schools and adjusted for the confounding potential of gender, parental educational attainment, and household income.

β** represents the intervention effect: the increase in physical activity among students attending APPLE Schools relative to the increase among students attending comparison schools. The estimations accommodated for clustering of students within schools and adjusted for the confounding potential of gender, parental educational attainment, and household income.

§ Intraclass Correlation Coefficient

To school*** was defined as activity accumulated between 8:00-8:59am

From school**** was defined as activity accumulated between 3:00-3:59pm