SCHOOL AND NEIGHBOURHOOD RECREATIONAL ENVIRONMENTS AND THEIR IMPACT ON PHYSICAL ACTIVITY PARTICIPATION AMONG CANADIAN YOUTH

by

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Abstract

Background: Less than half of Canadian youth meet recommended levels of physical activity. This is of concern given the health burden associated with physical inactivity. With the limited success of physical activity interventions, research has begun to focus on how physical and sociocultural environments affect physical activity. Investigation of school and neighbourhood characteristics that facilitate physical activity may identify environmental changes that could increase participation among adolescents.

Objectives: The objectives of the two studies comprising the thesis were to examine, among youth in grades 6 through 10: 1) the association between school recreational characteristics and physical activity during free-time and class-time *at school,* and 2) the effects of perceptions of neighbourhood safety and availability of parks and recreational facilities on physical activity participation *outside of school*.

Methods: Data from the 2006 Canadian *Health Behaviour in School-Aged Children Survey (HBSC)* were analyzed. Multilevel logistic regression was employed to quantify associations between school and neighbourhood characteristics and physical activity. For the first study, student responses to school-time physical activity scales were dichotomized (≥ 2 vs. <2 hours/week). A cumulative index that considered together policies, varsity and intramural athletics, presence and condition of fields, and condition of gymnasia was constructed based on principals' reports. In the second study, physical activity outside of school was dichotomized (≥ 4 vs. <4 hours/week). A scale of individuals' perceptions of safety was constructed. The number of parks and recreational

facilities within a 5 km buffer of schools was abstracted from a geographical information system.

Results: *Objective 1.* School recreational features were modestly positively related to adolescents' physical activity at school, particularly that occurring during free-time. The cumulative effect of school recreational features exerted a stronger effect than any single feature. *Objective 2.* Perceptions of safety were associated with students' physical activity, whereas increased availability of parks and recreational facilities neither prevented nor promoted physical activity.

Conclusions: *Objective 1.* High levels of recreational support at schools might promote physical activity among young people. This could inform educational policies and support funding of school recreational opportunities. *Objective 2.* Improving perceptions of safety might promote physical activity participation among youth.

Co-Authorship

This thesis presents the work of Marianne Nichol in collaboration with her advisors, Dr. William Pickett and Dr. Ian Janssen.

Manuscript 1: *Associations between school recreational environments and physical activity*. The idea of using the *HBSC* and the *HBSC Administrator Survey* to examine the effects of school features on students' physical activity was Dr. Janssen's. The idea of incorporating a cumulative scale of school facilities was Dr. Pickett's. The writing of the manuscript, the statistical analysis and the interpretation of the results were the work of Marianne Nichol, with supervision and editorial feedback provided by Dr. Janssen and Dr. Pickett. Classification of schools by geographical location (i.e. urban/rural location) was the work of Laura Seliske.

Manuscript 2: *Perceptions of neighbourhood safety, not recreational facilities, are associated with physical activity in youth.* The idea of using the *HBSC* to examine the effects of availability of neighbourhood facilities on students' physical activity was Dr. Janssen's and Dr. Pickett's. The idea of incorporating perceptions of safety arose out of discussion between Marianne Nichol, Dr. Janssen and Dr. Pickett. The idea of using a scale of facility availability was Dr. Pickett's; the method for constructing the scale was proposed by Dr. Janssen. Marianne Nichol identified *CanMap Streetfiles* as an appropriate geographical information system and collected information on numbers of parks and recreational facilities around schools. Laura Seliske collected information on

geographical location (urban/rural) and area-level socioeconomic status; these represent potential covariates within this analysis. Marianne Nichol performed the statistical analysis, interpreted the results, and wrote the manuscript. Dr. Janssen and Dr. Pickett provided conceptual and editorial feedback.

Marianne Nichol wrote other chapters of the thesis (introduction, background and literature review, general discussion, and appendices), with editorial feedback and advice from Dr. Pickett and Dr. Janssen.

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Chapter 1
Introduction

1.1 General Overview

Physical inactivity is one of the leading determinants of morbidity and mortality in Canada, having been shown to increase an individual's risk of developing hypertension, type 2 diabetes, cancer, and ischemic heart disease[1]. Physical inactivity is highly prevalent in Canada, with more than half of Canadian adults and adolescents reporting being physically inactive in 2001[2,3].

The causes of physical inactivity in adolescence are multifaceted and exist at varying levels of Canadian society. These potential determinants include not only individual-level characteristics (such as knowledge, attitudes, socioeconomic status, age, and gender) but also those at the macro- and micro-environmental level. Macro-environmental characteristics include policies at government levels, transport infrastructures, and media influences[4]. Micro-environmental factors are those that act more proximally, at the level of homes, schools and neighbourhoods[4].

Using multilevel statistical methods, the research within this thesis will further explore relationships between school and neighbourhood characteristics, specifically the provision of recreational opportunities and facilities and neighbourhood safety, and physical activity participation in Canadian adolescents.

1.2 Scientific Importance

Recently, the Canadian Institutes of Health Research in partnership with the Heart and Stroke Foundation have made the effect of the built environment on physical activity

a research priority[5]. As defined by CIHR, the built environment is the outcome of community planning, design and implementation[5], in other words the man-made physical spaces in which people live.

Two systematic reviews have recently highlighted the lack of research examining environmental characteristics of schools and neighbourhoods associated with physical activity in youth[4,6]. Of the studies that do exist, most have explored the effect of the perceived environment; few have used objective measures of physical environments, geographical information systems and multilevel statistical techniques[4,6]. The effects of built neighbourhood features on physical activity in Canadian adolescents have yet to be explored.

Using data from the 2006 Canadian *Health Behaviour in School-Age Children Survey* and a nationwide geographic information system (*CanMap Streetfiles*), the aim of the thesis is to explore relationships between the school and neighbourhood environments and physical activity in youth. The current study will improve upon previous research through use of a multilevel approach, a large nationally representative sample of nearly 10,000 adolescents in grades 6 through 10, context-specific measures of physical activity, and objective measures of the school and neighbourhood environment.

1.3 Societal Importance

Physical inactivity is an important determinant of morbidity and mortality, placing a significant economic burden on Canadian society[7]. Increases in the level of physical activity in youth could not only translate into immediate health benefits, but also reduce the incidence of physical inactivity-related chronic diseases in the future. By

following a mass strategy for disease prevention, small increases in individuals' physical activity (and resultantly small reductions in individuals' risk of disease) would translate into a larger reduction in the health risk of the population as a whole[8]. Even if this research detects only small area-level effects in individuals, the population attributable risk associated with the area-level factors would be greater as the majority of youth are exposed to the school and neighbourhood environment. Thus, the impact on the health of the entire population could be much greater[9].

Because the vast majority of youth are exposed to the school environment, schools provide an important arena for health promotion and provide opportunities to participate in physical activity[10]. By identifying school features that are protective against physical inactivity, this analysis may point towards practical interventions and policies aimed at increasing physical activity in youth. Physical improvements to the school environment may lead in turn to better levels of physical activity.

Similarly, neighbourhood characteristics beyond school properties can impact upon physical activity levels not only in children and youth but also the entire community. Identification of neighbourhood factors that promote physical activity may lend support for the improvement of current obesogenic environments. Such environmental planning could increase physical activity in the entire community, thereby reducing the future burden of physical inactivity-related diseases.

1.4 Empirical Objectives and Hypotheses

1. To examine school characteristics and their association with physical activity *during school hours* among youth in grades 6 through 10. It is hypothesized that

the presence of a playing field, the condition of physical activity facilities, and the presence of school policies to increase physical activity will each be positively associated with physical activity during *class-time*. In addition to these factors, availability of late bus services for extracurricular activities and the number of varsity and intramural sports offered at the school are each expected to be positively associated with physical activity *during free-time* at school. It is expected that schools will not differ widely with respect to the presence of gymnasiums and physical activity in the curriculum; an effect on the basis of these exposures will not be detectable.

2. To examine the independent and interactive effects of individual perceptions of neighbourhood safety and availability of parks and recreational facilities on physical activity participation *outside of school* in youth in grades 6 through 10. It is expected that perception of neighbourhood safety will be independently associated with physical activity *outside of school*. In addition, it is anticipated that the number of parks, trails and publicly provided recreational facilities within 5 kilometres of schools will be positively associated with physical activity, particularly in neighbourhoods perceived as safe by students.

1.5 Thesis Organization

This thesis conforms to the regulations outlined in the Queen's School of Graduate Studies and Research "General Forms of Theses"[11]. The second chapter summarizes previous studies in the areas of school- and neighbourhood-level physical

activity research. The third chapter of the thesis is Manuscript 1 and is an analytic study exploring the relationships between school characteristics and physical activity in Canadian adolescents. This manuscript has been formatted for submission to the *American Journal of Preventive Medicine*. Chapter 4 of the thesis is the second manuscript, prepared for submission to *Pediatrics*. It examines associations between perceptions of neighbourhood safety, publicly provided recreational spaces and physical activity participation in Canadian youth. Chapter 5 contains a summary of findings, a general discussion, and conclusions.

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Chapter 2
Background and Literature Review

2.1 Introduction

The purposes of this chapter are to introduce the problem of physical inactivity among Canadian adolescents and its consequences, and to review the state of the existing literature evaluating the impact of school and neighbourhood characteristics on physical activity in adolescence. "Adolescence" usually refers to the period of development from puberty to adulthood, ranging from roughly age 10 to 18 years. Because the majority of studies in this area have used student populations drawn on the basis of grade, for the purpose of this review "adolescence" has been defined as the academic period from grade 6 through to the end of high school. Throughout the thesis the terms "youth", "young people", and "teenagers" will be used synonymously with "adolescents".

With respect to schools, particular focus will be given to the effects of policies for physical activity and provision of recreational opportunities and facilities. The main neighbourhood characteristics under consideration are parks and recreational facilities and neighbourhood safety. Throughout the thesis, the use of the term "environment" will refer to the built or man-made environment, and not the social or natural environment. This chapter concludes with directions for future research.

2.2 Prevalence of Physical Activity in Adolescence

Canada's Physical Activity Guide for Children and Youth currently recommends that youth 10 to 14 years of age gradually increase their moderate intensity physical activity by 60 minutes per day and their vigorous intensity physical activity by 30

minutes per day over the course of five months[1]. The Centers for Disease Control and Prevention in the United States recommend that children and youth engage in 60 minutes of moderate-to-vigorous physical activity on most if not all days of the week[2]. Moderate-to-vigorous physical activity is that which significantly increases one's heart rate, breathing, and body temperature.

Only 45% of Canadian youth in grades 6 through 10 are physically active for 60 minutes at least 5 days per week[3]. Such low rates of physical activity are of particular concern not only because this behaviour may track into adulthood, as demonstrated in a recent review of 13 studies conducted by Hallal et al.[4], but also because the health benefits of physical activity can be seen as early as adolescence[4].

2.3 Health Benefits of Physical Activity

Adolescent physical activity has been associated with both short- and long-term health benefits. Some of the immediate benefits include higher self-esteem, lower levels of depression, reduced stress and reduced anxiety[4,5]. Adolescent physical activity may also influence adult health independent of physical activity levels in adulthood. For example, adolescent physical activity may protect against fracture in adulthood, regardless of adult physical activity levels, due to optimization of peak bone mass in adolescence[4]. Adolescent physical activity may also be associated with lower risk of developing breast cancer independent of adult activity levels, although results are somewhat mixed; 16 case-control studies have demonstrated an association whereas 3 cohort studies have not[4]. In addition, establishing appropriate levels of physical activity early in life and having the behaviour maintained throughout the course of adulthood has

the potential to substantially reduce the burden of physical inactivity-related chronic diseases. According to the World Health Organization[6], 10 to 16% of type 2 diabetes, breast cancer, and colorectal cancer cases are attributable to physical inactivity. In addition, 22% of ischemic heart disease cases are estimated to be the result of physical inactivity[6].

Not only is physical inactivity a risk factor for premature mortality independent of adiposity levels[7], it is also a determinant of obesity[8], an independent risk factor for many chronic diseases. Like physical inactivity, obesity rates in Canada are of epidemic proportions, even among children and adolescents. Recent findings based on measured heights and weights estimate that approximately 26% of Canadian children ages 2 to 17 years are overweight or obese[9], with the prevalence of obesity having tripled in the past 25 years among youth[9]. Physical inactivity is a determinant of future weight gain and obesity in adult populations[8]. Thus, establishment of a healthy active lifestyle early in life has the potential to reduce future risk of developing obesity and resultant chronic diseases.

2.4 Influence of Individual Characteristics on Physical Activity

In an extensive literature review, Sallis et al.[10] summarized the associations between individual-level characteristics and physical activity in adolescents aged 13 to 18 years using results from 54 analytic studies. The authors found that gender was the most consistent correlate of physical activity, with girls being less physically active than boys[10]. As well, the majority of studies demonstrated an inverse association between age and physical activity. Ethnicity was also consistently associated with physical activity,

with higher levels of physical activity among non-Hispanic white adolescents[10]. No study to date has explored the association between ethnicity and physical activity among Canadian children or adolescents; one study conducted among Canadian adults found the prevalence of being moderately physically active was higher among White Canadians and Aboriginals (49% and 47%, respectively) and lower among Asian, Arab, Black, and Hispanic Canadians, with prevalence ranging from 34% to 40%[11].

The review by Sallis et al.[10] concluded that socioeconomic status was unrelated to physical activity. However, the majority of studies included in the review were conducted in the United States; a more recent Canadian study[12] found that both increased material wealth and higher perceived socioeconomic status were significantly positively associated with physical activity in adolescents.

Results of studies examining the influence of parents and other family members on adolescents' physical activity levels are mixed. In their review, Sallis et al.[10] concluded that parent physical activity was unrelated to adolescent physical activity and that the relationship was indeterminate among children. In another recent review, Ferreira et al.[13] found that the physical activity behaviour of parents, siblings, and peers was unrelated to adolescent physical activity in most studies. The Sallis et al. review found that help and support from parents and significant others was consistently associated with teenagers' physical activity; however, the Ferreira et al. review concluded that the effect of parental and family support on physical activity was unclear[13].

Over the past 20 years, many interventions, based on behavioural theories such as the Health Belief Model and Social Cognitive Theory (as cited in 14), have been

developed with the focus of changing the physical activity behaviour of individuals[14]. Despite these efforts, physical inactivity and obesity are still of epidemic proportions. Increasingly, more interest has been placed on higher-level environmental and cultural factors that may promote or hinder physical activity in populations. Along these lines, Sallis et al.[15] have developed an ecological model describing the higher-level variables that might affect different types of physical activity. This model divides active living into four different components: recreation, transport, occupation, and household activities, and suggests hypotheses about the intrapersonal, perceived, environmental and policy factors that may influence each. Research evaluating these different potential predictors or inhibitors of physical activity may drive future intervention strategies that target populations as well as individuals. This review focuses particularly on school and neighbourhood factors potentially associated with adolescents' recreational activities.

2.5 Literature Search Strategy

Studies of the effects of school and neighbourhood environments on adolescent physical activity were identified in Medline/Pubmed using the key words: 'physical activity', 'adolescence', 'adolescents', 'childhood', 'children', 'school', 'neighbourhood', 'environment', 'built environment', 'parks', 'facilities', and 'safety'.

2.6 Influence of Schools on Physical Activity

Children and youth spend a significant proportion of their time at school, and as such schools have the potential to influence health behaviours through the provision of facilities and opportunities for physical activity[16]. In addition, schools provide recreational support and instruction from trained educators[17]. There is, however, a paucity

of studies examining the effect of schools on physical activity in children and adolescents[13]. Many studies have investigated school-based interventions for increasing physical activity, but few observational studies have considered the effects of policies, recreational opportunities and physical facilities in schools[13].

2.6.1 School Policies and Recreational Opportunities for Physical Activity

The prevalence of policies and opportunities for physical activity among schools has been described in both Canadian[18-20] and American[21-25] settings. However, to my knowledge, no studies have assessed the impact of having school policies or other recreational opportunities (such as intramural or varsity sports programs) on students' physical activity levels.

2.6.2 Recreational Facilities in Schools

Only three analytic studies[26-28] have examined the effect of school recreational facilities on physical activity in children or youth. Recreational facilities are school areas designed for sports and physical activity, such as gyms, playing fields, weight rooms, and running tracks.

Sallis et al.[26] observed the proportion of grade 6-8 students engaging in moderate-to-vigorous intensity physical activity before and after school and during recess across 24 middle schools in San Diego, California. The gender-specific regression models explained 42% and 59% of the variance in non-physical education physical activity for girls and boys, respectively. In particular, these authors reported that girls were more physically active when both high levels of supervision and supportive features (e.g. basketball hoops, baseball diamonds, football/soccer goals) were present; this

interaction explained 11% of the variance for girls. Boys were more physically active on courts with high supervision, with this interaction explaining 16% of variance in non-physical education physical activity. However, regardless of the physical environment, in the schools under investigation <6% of the students were observed being moderate-to-vigorously active. One limitation of this research may be observer bias, since both physical characteristics and the number of students being physically activite were determined by direct observation by data collectors. It would be difficult to blind collectors to the exposures of interest (the environments in which students were observed). As such, it is possible that data may have been collected differently depending on the school features present or absent at each school. A second limitation of this study may be lack of generalizability, as the results of the study may not be applicable to settings outside of San Diego, California.

A second study, conducted by Fein et al.[27], found that an index of the perceived availability of school facilities was weakly positively correlated (Pearson $r=0.15$, $p<0.01$) with adolescents' self-reported physical activity in a sample of 610 grade 9 to 12 students in four rural Albertan high schools. Students provided Likert responses to twelve statements that included "The gym space allows me to do all the activities I want", "The sports or exercise equipment works well" and, "The athletic facilities at my school are easily accessible to me." The other 9 scales used to construct the index were not described. In addition, the respective importance of each scale was not investigated[27]. Because this study used perceived rather than objective measures of the school environment, a potential limitation may be recall bias. Recall bias may have occurred if

active students rated their environment more favourably compared with inactive students. In other words, although the school environment could in fact be the same, differences may have emerged due to differences in perception. In addition, Likert scales may be subject to central-tendency bias (individuals' tendency to avoid extreme response categories) or acquiescent bias (individuals' tendency to agree with statements)[29], either of which could result in non-differential misclassification. Finally, like the previous study, this research was limited to a geographically limited setting and thus the results may not be widely generalizable.

Using a sample of 256 students in 7th and 8th grade across 10 school sites in Boston, Massachusetts, Cradock et al.[28] found school campus area, play area and building area to be each positively associated with students' physical activity during the school day. Physical activity was measured objectively using accelerometers. School campus, play, and building areas were determined based on land-use parcel data obtained from local government offices, site visits, geometrically corrected aerial photographs (i.e. orthophotos), architectural plans, and site maps. Of the three school studies identified herein, this is the only one that used multilevel modelling to take into account the clustered and hierarchical nature of the data. School campus area per student, play area per student and building area per student were each significantly associated with students' physical activity levels, after adjusting for age, gender, race, BMI, physical education days/week, and the time and day of physical activity measurements. For example, each one square metre increase in play area per student was associated with a 0.347 unit increase in log-transformed vector magnitude (a measure of movement). A few

limitations of this study should be noted. Because the size of campus, play, and building areas were correlated (r=0.60-0.89), the independent effects of each could not be disentangled[28]. Also, data were not collected simultaneously in schools and occurred between February and May. It is possible that seasonal differences in activity levels might have confounded relationships if for example smaller schools were measured during the winter and larger schools in the spring. Finally, the use of log-transformed accelerometer data makes interpretation of the strength of associations difficult.

2.6.3 Summary of School Research

In summary, very few studies have explored the effects of school environments on students' physical activity levels. No studies have considered the effects of school policies or recreational opportunities on teenagers' physical activity levels. The three studies summarized above have identified weak relationships between school facilities and physical activity in youth. The major limitation of these studies is that each was conducted in geographically limited area, and as such the generalizability of results is questionable.

In general, further research is needed to explore the importance of physical education, policies, recreational opportunities (such as sports programming) and facilities on physical activity. Ideally such research should be conducted in larger and more geographically diverse populations so that results may be generalized to either the Canadian or American adolescent population.

2.7 Influence of the Neighbourhood Environment on Physical Activity

Similar to school-level research, few studies have examined the effect of the physical neighbourhood environment on physical activity in youth[13]. Recent research[30] has found that aspects of the built neighbourhood environment influence physical activity participation in adults over and above the influence of individual-level characteristics. These environmental features include street-connectivity (i.e. walkability of the street network), land-use mix (i.e. the mix of residential and commercial use) and the density of physical activity facilities[31].

Associations observed in adults may or may not hold for younger people, who when compared with adults have more time for recreation, tend to accumulate physical activity through play, and engage in more spontaneous physical activity behaviours[5]. In addition, because youth are not able to drive and are generally less autonomous[5], their activities may be limited to their more immediate neighbourhood surroundings. As such, access to local parks and public facilities may be especially important for encouraging physical activity in young people. Neighbourhood safety may also be an important factor for children and youth, as it likely drives parents' decisions to allow their children to play outside and use neighbourhood recreational facilities.

2.7.1 Parks and Physical Activity in Adolescence

As a definition, a park is a public section of land provided and maintained by municipal or provincial/state governments for outdoor recreation[32]. Parks often contain features for passive enjoyment (such as benches and picnic tables) or features for active recreation (such as baseball diamonds, outdoor hockey rinks, and walking/running trails).

Parks often also contain features specifically designed for use by young children, such as playgrounds and swings. Because teenagers are less autonomous and often bound to their immediate neighbourhoods as they are unable to drive, parks may be important supports for their participation in physical activities. Five existing studies[33-37] have examined the association between parks and physical activity in adolescents. Three of these considered perceived availability[33-35] whereas the other two used objective measures of neighbourhood parks[36,37].

2.7.1.1 Perceived Availability of Parks

In a cross-sectional study of 8th and 9th grade girls, Motl et al.[33] found that perceived availability of parks together with perceived availability of neighbourhood gyms and sports equipment in the home was significantly associated with self-reported physical activity. Because this study did not separate the effects of parks from other environment supports (e.g. gyms, home equipment), the independent effect of parks was not measured. As with the school-level research that used perceived environmental measures, the use of perceived measures of parks may be subject to recall bias if those who are physically active and inactive perceive the same environment differently. Although this bias has not been demonstrated in adolescents, Kirtland et al.[38] compared self-reported neighbourhood characteristics to objective measures among 1112 American adults, and demonstrated that active adults were more likely to accurately report public recreation facilities compared to inactive adults (κ=0.35 vs. κ=0.16, respectively).

Utter et al.[34] concluded that New Zealand adolescents aged 13 to 17 years who perceived living within walking distance of a park were 1.17 (95% CI: 1.1-1.3) times

more likely to be vigorously active for 20 minutes three days per week compared to youth who did not live within walking distance of a park. The magnitude of association should be interpreted with caution; since physical activity (the outcome) was not rare in this population, with approximately 50% being active, the odds ratio will overestimate the relative risk. Another limitation of this study is the use of perceived environmental measures. Not only did this study depend on perceived availability of facilities, perceived availability was dependent on perceived distance. For example, a "walkable" distance for an active adolescent may be much greater than that of an inactive one and since the area is larger, an active student would be more likely to report a park within walking distance.

Both of these studies[33,34] used measures of overall physical activity (i.e. context-free measures) rather than context-specific measures of physical activity. Context-specific measures take into consideration the settings in which physical activity behaviour takes place, for example at school or outside of school. As suggested by Giles-Corti[39], estimates may be diluted through use of overall physical activity measures. In other words, having the behaviour of interest more closely match the environmental characteristic would improve the predictive ability of a model[39].

Alton et al.[35] considered a context-specific measure of physical activity (walking trips outdoors) and its association with neighbourhood parks among youth age 9 to 11 in the United Kingdom. The researchers found that youth who reported more than the mean number of walking trips (high walkers) were 1.51 (95% CI: 0.98-2.38) more likely to report having parks in their neighbourhoods, after adjusting for grade, sex, ethnicity, and

car ownership. Like the previous studies, the results of this study may have been subject to recall bias due to the use of perceived measures.

A common limitation of these three studies is the use of self-reported physical activity, which could result in either non-differential or differential misclassification. Individuals are expected to over-report their physical activity participation due to social desirability[40,41]. If this over-reporting occurs independent of exposure (in this case neighbourhood features), the misclassification would be non-differential and effect estimates would be diluted towards the null. If, on the other hand, having parks and other recreational features in the neighbourhood causes physical activity to be viewed as a more normative and socially desirable behaviour, adolescents exposed to these features may be more likely to over-report their physical activity compared to youth not exposed to these neighbourhood features.

Another common limitation is the use of perceived measures of the environment, as has previously been explained. A few studies have, however, considered objective measures of parks.

2.7.1.2 Objective Availability of Parks

Norman et al.[36] considered the objective number of parks (as well as the number of recreational facilities) within 1 mile (1.6 km) of individuals' homes and its association with objectively measured moderate-to-vigorous physical activity among 11 to 15 year old adolescents living in San Diego, California. The locations of parks were determined according the geographic information system database of the San Diego Association of Governments. The authors found that number of parks was significantly but weakly

correlated with girls' physical activity ($r=0.14$, $p<0.01$); no association was observed for boys. However, once both number of parks and number of facilities was entered into a multilevel linear regression model, parks were no longer significantly associated with girls' physical activity. However, lack of association in the multivariate model may have been due to colinearity between neighbourhood parks and facilities; correlation between facilities was not investigated. This study may also be limited by its use of total rather than context-specific physical activity.

In a sample of 1556 American grade 6 girls, Cohen et al.[37] found that each one park increase within a half mile radius of girls' homes (as determined objectively using a geographical information system) was associated with a 2.8% increase in moderate-to-vigorous physical activity participation outside of school time. Unlike the Norman et al. study that used total physical activity as the outcome, Cohen et al. considered only physical activity that occurred outside of school hours.

A strength of both of these studies[36,37] was their use of objective measures of physical activity and parks, thereby avoiding the problems associated with self-report physical activity and perceived environmental measures. Another strength of these studies is that both used multilevel linear regression to account for the hierarchical nature of the data and clustering by school. The studies may be limited through use of circular buffers (radii) around individuals' homes as approximations of neighbourhoods, as it remains unclear what radial distance is relevant for youth or adults[42]. In addition, circular buffers do not consider physical barriers (such as freeways, railways, rivers etc) that might make locations inaccessible[42]. It might have been possible to use network buffers

as an alternative to circular buffers. This more complicated method uses road distances instead of radii to construct a polygon area around individuals' homes. As such, a network buffer may more accurately reflect "walkable" areas. This method may not however be equally accurate for different types of street networks (e.g. urban dense grid networks vs. less dense suburban network)[42]. Despite the limitations of circular buffers, the above studies did find modest associations; it is possible that use of more accurate measures of neighbourhoods might lead to stronger associations.

2.7.1.3 Summary of Parks Research

In summary, there have been five studies exploring the association between access to parks and physical activity participation in youth, all of which have been cross-sectional in nature. To date, no studies investigating the effects of parks have been conducted in Canada. In general, the identified studies suggest that the presence of parks is weakly associated with adolescents' physical activity participation, despite differences in methodology and some limitations. Although the effect sizes are small, small increases in individuals' physical activity (and resultantly small reductions in individuals' risk of disease) could translate into a larger reduction in the health risk of the population as a whole[43]. Thus, even small area-level effects in individuals may be meaningful, as the impact on the health of the entire population could be much greater[37].

2.7.2 Recreational Facilities and Physical Activity in Adolescence

As with parks, there has been little research exploring the effect of other recreational facilities, such as gymnasia, community centres and pools, on activity levels in young people. Only six studies were identified in a literature search[34,36,44-47]. Four of

these studies used perceptions of facility availability as the exposure of interest[34,44-46], whereas the other two[36,47] used objective measures.

2.7.2.1 Perceived Availability of Recreational Facilities

The study by Utter et al.[34], previously identified in *Section 2.6.1.1,* also found that New Zealand youth aged 13 to 17 years who self-reported that there was a swimming pool, gym, and youth centre within walking distance of their home were 1.38 (95% CI: 1.20-1.50), 1.44 (1.30-1.60), and 1.11 (0.90-1.30) times more likely, respectively, to be physically active compared to those who did not report living in close proximity to such facilities. The limitations of this study were summarized in *Section 2.6.1.1.*

In a sample of 74 low-income American youth aged 10 to 16 years, Romero[44] found that self-reported vigorous physical activity was significantly correlated with perceived facility quality ($r=0.28$, $p<0.05$) but not significantly correlated with perceived availability ($r=0.18$, $p>0.05$). Availability of facilities was measured using an index that considered not only the presence of certain facilities (namely community centres, outdoor park/facility, YMCA/YWCA, school playgrounds, backyards, and home gyms) but also whether each of these was free, paid for by parents, within walking distance, and whether other transportation was available. The lack of statistical significance with respect to perceived facility availability was likely due to the small sample size of 74.

Both of the above-mentioned studies[34,44] used overall measures of physical activity rather than focusing on more specific types of physical activity, for example that which occurs outside of school. These studies also relied on self-reported measures of physical activity. These two limitations have been previously addressed in *Section*

2.6.1.1. Two studies of perceived facility availability[45,46] have addressed these limitations by considering only moderate-to-vigorous physical activity outside of school, measured objectively using accelerometry.

Evenson et al.[45] found that girls who reported having 9 to 14 facilities that were easy to get to from home or school had physical activity levels that were 15.3% higher than girls reporting access to 4 or fewer facilities. Fourteen types of facilities were considered together: basketball courts, beach/lakes, golf courses, health clubs, martial arts studios, fields, parks, recreation centres, tracks, skating rinks, pools, trails, tennis courts, and dance/gymnastic clubs. The independent effects of these facilities were not considered. If some of these features were strongly associated and others not, the effect of the combined measure would have been diluted.

Using the same population of grade 6 girls, Scott et al.[46] addressed this limitation by considering the separate effects of 9 of the 14 above-listed facilities on non-school physical activity. The authors considered each facility in a separate multilevel linear regression predicting log-transformed non-school minutes of moderate-to-vigorous physical activity, controlling for individuals' socioeconomic status, race, population density, and objective measures of the environment. The study found that perceived availability of basketball courts (ß=0.10), golf courses (ß=0.14), playing fields (ß=0.10), running tracks (ß=0.13), pools (ß=0.12), and dance/gymnastic clubs (ß=0.06) was each significantly but weakly linearly associated with girls' non-school minutes of physical activity (log-transformed), but that martial arts studios and skating rinks were not.

2.7.2.2 Objective Availability of Recreational Facilities

Three studies have considered objective measures of the neighbourhood environment[36,46,47]. The study by Scott et al.[46] considered not only the effects of perceived but also objective measures of facilities on grade 6 girls' physical activity levels. Unlike perceptions of facility availability, objectively measured facilities were not associated with girls' physical activity, with the exception of basketball courts, after controlling for grade, socioeconomic status, population density and perceived measures. Based on regression models that included both the perceived and objective measure of the facilities, the authors concluded that perceptions of facilities were associated with physical activity independent of objective measures. The authors concluded that objective facilities were not associated with physical activity.

Norman et al.[36] examined the number of public and private recreational facilities within 1 mile of individuals' homes and found this was weakly correlated ($r=0.11$, $p<0.016$) with physical activity among females but not males. Together with number of parks and intersection density, these measures of environment explained 3% of the variance in minutes per day of moderate-to-vigorous physical activity[36]. The strengths and limitations of this study were presented in *Section 2.6.1.2*.

Using geographic information systems and multi-level modelling, Gordon-Larsen et al.[47] found that objective measures of the number of recreational facilities within 8 km of homes was significantly positively related to physical activity in a sample of 20745 American adolescents. Compared to those with no recreational facilities in their neighbourhood, those with one facility had 1.03 (95% CI: 1.01-1.06) times the odds of

engaging in self-reported moderate to vigorous physical activity 5 or more times per week; those with 7 facilities had 1.26 (95% CI: 1.06-1.50) times the odds[47]. These findings are strengthened by the use of a large, nationally representative sample of American teenagers.

2.7.2.3 Summary of Recreational Facilities Research

In short, of the few studies that have investigated the effects of recreational facilities on physical activity among youth, most have found weak associations. With the exception of the Romero study[44], the studies identified have considered only availability and not affordability, quality or accessibility[47]. In addition, the effects of neighbourhood recreational facilities have not been examined in Canadian populations.

2.7.3 Neighbourhood Safety

In addition to availability of recreational spaces, both real and perceived neighbourhood safety may be important in influencing teenagers' physical activity. The safety of a neighbourhood may be described in terms of physical hazards that may cause injury to individuals while engaging in physical activity (such as road hazards, broken glass, discarded syringes) or social hazards (such as fear of strangers, abduction, and other types of crime.) How an individual perceives his or her environment may be important in influencing adolescent activity, irrespective of true levels of neighbourhood safety.

Ten identified studies have investigated the influence of varying aspects of neighbourhood safety on physical activity among youth[33-35,44,45,48-52]. Seven of these

considered the effects of teenagers' perceptions of neighbourhood safety[33-35, 44,45,48,49] whereas three have considered the effects of more tangible measures of safety[50-52].

2.7.3.1 Perceptions of Neighbourhood Safety

Five studies have reported a positive relationship between perceptions of neighbourhood safety and physical activity[34,35,44,45,48] whereas two found no association[33,49].

Utter et al.[34] found that perceptions of neighbourhood safety were positively associated with adolescents' (n=9699) physical activity participation in New Zealand. Youth who reported feeling safe in their neighbourhood had 1.46 (95% CI: 1.3-1.6) times the odds of self-reporting 20 minutes of vigorous activity at least 3 days per week, compared to youth who felt unsafe. This study did not evaluate different types of neighbourhood safety. It is unclear whether this construct measures the physical safety of spaces or other dangers (such as violence, crime, or strangers).

Mota et al.[48] investigated the cross-sectional association between perceptions of crime and self-reported leisure-time physical activity among Portuguese youth. Girls who felt that the crime rate made it unsafe/unpleasant to walk in their neighbourhood were less likely to be physically active during their leisure time (OR: 0.60; 95% CI:0.39-0.91); no association was observed for boys.

Romero[44] considered the effect of combined perceptions of neighbourhood hazards (traffic, trash, crime, noise, gangs, access to parks, prejudice, drugs) as well as perceptions of recreational facility safety on physical activity among 74 students aged 10-16 from a low-income neighbourhood. Feeling safe when certain adults are at facilities,

feeling that facilities are located in safe areas, and feeling safe when walking to facilities were each positively related to physical activity. Together these variables accounted for 13% of the variance in physical activity. Conversely, more perceived hazards were associated with increased physical activity, accounting for 4% of variance. The independent effects of the neighbourhood hazards of interest were not considered. Results of this study are likely not widely generalizable to other populations, as the study population represented only low-income individuals from one geographical region with crime rates well above the U.S. average.

Alton et al.[35] found differing effects of social and physical hazards on walking trips among 9-11 year old youth in the United Kingdom. Students who had more worries about strangers when out alone had a lower odds of achieving the mean number of walking trips (OR: 0.66; 95% CI: 0.45-1.02) whereas increased concerns about road safety was associated with an increased odds of walking (OR: 1.88; 95% CI: 1.27-2.80). The authors concluded that the former relation was likely causal whereas the latter was attributable to the fact that children who walk more frequently have greater exposure to the environment and more reminders from parents about being careful while walking outdoors.

These studies all made use of self-reported physical activity, the limitations of which have been described previously. Unlike these, Evenson et al[45] considered the effect of perceived crime on objectively measured non-school physical activity among grade 6 American girls. A neighbourhood safety scale was constructed from 4 variables of perceived safety (safe to walk/jog, walkers visible at night, amount of crime, and street

lighting). For every 1-unit increase on the safety scale, an increase of 4.6% in non-school moderate-to-vigorous physical activity was observed. However the direction of the association between the individual items comprising the scale differed; feelings of safety, visibility of pedestrians, and street lighting were positively related to physical activity, whereas perceptions of crime were inversely related. By combining these measures, the effect of the overall scale of perceived safety was likely diluted. The authors also considered the relative importance of perceptions of safety and perceptions of facility availability. Increased street lighting, increased traffic, having walking trails and access to facilities were independently associated with girls' non-school physical activity.

Unlike these five studies that found moderate relationships between perceptions of safety and physical activity, two studies found no association between these measures. The first[33] considered the cross-sectional and longitudinal effects of neighbourhood safety on physical activity among 8th and 9th grade girls in South Carolina, finding no associations. The authors used a scale of perceived safety that considered two questions together: feeling "safe to walk or jog alone in [the] neighbourhood" and difficulty walking in the "neighbourhood because of things like traffic, no sidewalks, dogs and gangs". The lack of association may be due to combining variables related to physical activity in different ways; along these lines, the Romero[44] study found that increased perceptions of similar hazards (traffic, gangs, etc) was associated with increased physical activity whereas feeling that facilities were unsafe was associated with decreased physical activity. Another possible reason was lack of variability in perceptions of safety, as the average safety score was quite high (7.5 on a scale ranging from 2 to 10)[33].

In a subsequent study[49], the authors reinvestigated the cross-sectional association between this perceived safety scale and physical activity among 12th grade girls in South Carolina. The authors found no association between perceptions of safety and physical activity.

2.7.3.2 Objective Measures of Neighbourhood Safety

Gomez et al[52] considered the effects of objectively measured density of violent crime within a half mile of homes on self-reported outdoor non-school physical activity among 7th grade mainly Mexican-American youth (n=177) living in San Antonio, Texas. In addition to objective measures, the authors also considered perceptions of neighbourhood safety. The authors reported that measures of violent crime and perceived safety were significantly independently related to girls', but not boys', physical activity outdoors.

Using objective measures of serious crime and a sample of nearly 18,000 American 7th to 12th grade students, Gordon-Larsen et al.[50] found that students in areas with the highest serious crime rates had 0.77 (95% CI: 0.66-0.91) times the odds of being within the highest category of self-reported moderate-to-vigorous activity. This study did not use multilevel modelling techniques. Higher-level data was disaggregated to the individual and was treated as though it were independent, likely leading to overestimates of significance[53].

One subsequent study using multilevel analyses found statistical significant associations between safety and physical activity. In their study of 1378 youth aged 12 to 16 years living in Chicago IL, Molnar et al.[51] considered the effects of objective social

and physical disorders as well as neighbourhood safety on physical activity outside of school. Using direct observation, the authors measured aspects of social disorder (presence of fighting, drinking, gangs, people selling drugs, prostitution) and physical disorder (the presence of graffiti, discarded cigarettes and beer bottles, abandoned vehicles, condoms, and syringes). A scale was constructed that considered the adult residents' (n=8782) perceptions of availability of places to play other than the street, safety of parks during the day and night, condition of equipment within parks, and awareness of other adults watching out for children. Teenagers' hours of extracurricular recreational activity per week were lower in areas deemed as unsafe, as well as areas with higher levels of social and physical disorder. Residents' perceptions of safety were most strongly related to youth physical activity; for every 1-unit increase on the scale assessing neighbourhoods as unsafe to play, a 1.44 hour/week decrease in physical activity was observed.

2.7.3.3 Summary of Neighbourhood Safety Research

Of the ten identified studies, the majority have found moderate associations between measures of neighbourhood safety and physical activity among youth. The majority of studies have been cross-sectional; it is plausible that individuals' physical activity behaviour influences their perceptions of safety through increased exposure to the environment, rather than perceptions influencing physical activity. To date no study has investigated the effects of perceived or objective safety on physical activity in a defined population of Canadian adolescents. In general the studies have been limited to small geographic regions, typically within larger urban areas.

2.8 Summary and Directions for Future Research

In short, based on the identified studies, both school and neighbourhood characteristics appear to be associated with physical activity in adolescence. Neighbourhood-level research has developed more widely than school-level research, which is surprising given that schools are ubiquitous and provide both facilities and opportunities for physical activity. The greater amount of neighbourhood-level research, as compared to school-level research, may have occurred as a result of prior studies in adult populations and the desire to extend results of these studies to younger populations.

The majority of adolescent based research appears to support the idea that neighbourhood facilities are weakly associated with adolescents' physical activity levels. Stronger associations have been observed for neighbourhood safety. This may suggest that safety is more important in influencing physical activity than availability of parks and facilities. However, only one study to date has simultaneously considered the effects both safety and facility availability[45]; as such, it remains unclear if safety and availability of recreational features are independent predictors of physical activity and if so, which are the strongest. This presents a unique research question to be investigated in this thesis.

Research in the area of neighbourhood determinants of physical activity is required, not only to determine the temporality of associations and the relative importance of neighbourhood characteristics, but also in developing a standard approach to measuring physical activity and the environment in order to increase comparability between studies. The effects of school characteristics on physical activity are even less

clear, due to the small number of studies in this area. Few studies of schools have focused on facilities; no studies have considered the effects of policies or recreational opportunities on physical activity in youth. The majority of existing studies have been conducted in small geographically limited populations. Larger, more diverse, populations should be studied in the future.

The effects of neighbourhood and school characteristics on rates of physical activity have yet to be extended to the Canadian context. With the exception of the two Canadian studies exploring area-level socioeconomic status[12] and the school environment[27], no other studies were identified exploring the effects of school and neighbourhood characteristics on physical activity in Canadian adolescents.

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Chapter 3
Manuscript 1: Associations between school recreational environments and physical activity

This manuscript conforms to the specifications for submission to the peer-reviewed journal

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Abstract

Background: School environments may promote or hinder physical activity among young people. The purpose of this research was to examine relationships between adolescent physical activity, the overall school recreational environment, and individual school characteristics.

Methods: Using multilevel logistic regression, data from 7638 grade 6-10 students from 154 schools who participated in the 2005/06 Canadian Health Behaviour in School-Aged Children Survey were analyzed. Student responses to validated physical activity scales were dichotomized (≥ 2 hours/week vs. <2 hours/week). Using principals' reports, a cumulative index was constructed that considered together: policies, varsity and intramural athletics, presence and condition of fields, and condition of gymnasia.

Results: Moderate gradients in physical activity were observed according to number of recreational features/opportunities. Overall, students at schools with more recreational features/opportunities experienced higher rates of class-time and free-time physical activity; this was strongest among high school students. Boys' rates of class-time physical activity were 1.53 (95% CI: 1.12-1.80) times higher at high schools with the most recreational features compared to those at schools with the fewest ($p_{trend} < 0.05$). Similarly, girls' rates of free-time physical activity at school were 1.62 (95% CI: 0.96-2.21) times greater at high schools with the most opportunities/facilities compared to those at schools with the fewest ($p_{trend} < 0.05$). Modest associations were observed between individual school characteristics and class-time and free-time physical activity.

Conclusions: Taken together, the cumulative effect of school recreational features may be more important than any one characteristic individually. School policies surrounding physical activity require tailoring to specific grades and genders.

Introduction

The Centers for Disease Control and Prevention recommend that children and youth engage in 60 minutes of moderate-to-vigorous physical activity on most if not all days of the week[1]. In a recent survey of 10-15 year olds from 34 countries, less than 50% of the participants within each country achieved this guideline of at least 5 days per week[2]. These low physical activity rates are concerning. The health benefits of physical activity are seen as early as adolescence[3], and this behaviour may track into adulthood where the health consequences are more evident[4].

Given the limited success of interventions that have attempted to increase physical activity by focusing on individual behaviour modification, research has begun to focus on how physical and sociocultural environments affect physical activity[5]. In their ecologic framework for active living, Sallis et al.[5] propose that physical activity is influenced by intrapersonal characteristics (e.g. beliefs, education) as well as physical characteristics of neighbourhoods, homes, and schools in which individuals live. Investigating environmental characteristics that facilitate physical activity may identify environmental changes that could increase participation[5].

Because young people spend a significant portion of their time at school, schools have the potential to influence physical activity through the provision of facilities and opportunities[6], recreational support, and instruction from trained educators[7]. Surprisingly, few studies have examined the effects of the school recreational environment on students' physical activity participation[8]. In four existing studies weak relationships were found[9-12]. Each of these studies was conducted in small samples in

geographically limited areas. No existing observational studies have considered the effects of school athletic opportunities and policies on different components of physical activity participation at school (e.g. during class- or free-time).

The purpose of this study was to explore the individual and combined importance of physical education policies, recreational opportunities (e.g. sports programming), and facilities on physical activity participation at school. The present study is the first to simultaneously examine relationships between all of these school characteristics. The use of a large, nationally representative sample and a multilevel modeling approach were additional methodological strengths.

Methods

Design

This research involved an analysis of cross-sectional data from the 2005/06 Canadian *Health Behaviour in School-Aged Children Survey (HBSC)*. The *HBSC* collected information on demographic characteristics, health behaviours, and health outcomes from students in grades 6-10 in publicly funded schools across all Canadian provinces and territories. Youth attending private, special-needs, or home schools were excluded, as were institutionalized, incarcerated, or homeless youth[13]. Consent was solicited from school boards and individual schools; parental and individual consent was obtained from all participants. The survey is self-weighting and used a cluster sampling design, with randomly selected classrooms reflecting the provincial distributions of schools by size, location, language, and religion[13]. The Canadian HBSC was conducted

in collaboration with the World Health Organization and follows an established international protocol[13].

The principal or vice-principal of participating schools completed an *Administrator Survey* that requested information about school characteristics, including the size and demographic distribution of the school, programs and activities, availability of facilities and the condition of facilities. This *Administrator Survey* was subsequently linked to individual-level information from the student participants.

Sample

The HBSC collected information from 9672 youth in grades 6-10 from 188 schools. Thirty-four schools were not included because the administrator survey was incomplete (19 schools) or because they could not be linked to student information (15 schools), leaving 7836 students from 154 schools. Of these, 198 students were excluded due to incomplete physical activity information, leaving 7638 (79.0%) students for analysis.

Measures

Outcomes – Physical activity at school

Outcomes of interest were participation in moderate-to-vigorous physical activity at school during 1) *class-time* and 2) *free-time*. Students provided ordinal responses to the questions: "about how many hours a week do you usually take part in physical activity that makes you out of breath or warmer than usual in your [class time/free time

(example lunch)] at school?" There were 9 response categories for both questions ranging from "none at all" through "7 or more hours". Responses were grouped to create two dichotomous outcomes: 1) physically active during class-time at school (≥2 vs. <2 hours/week) and 2) physically active during free-time at school (≥2 vs. <2 hours/week). Total physical activity is composed of activities that occur inside and outside of school; as such a threshold of 2 hours per week during free-time and class-time were respectively assumed to be consistent with the physical activity guideline for 60 minutes of moderate-to-vigorous physical activity on most if not all days of the week[1]. These thresholds reflect the amount of physical activity met by ~45% of students, consistent with the overall rate of physical activity participation in Canadian youth[2]. A dichotomous outcome was used so that results would be easily interpretable for health policy[14].

Exposures – School recreational environment and policies

Principals answered questions about the condition and availability of school recreational facilities, and the presence of recreational policies, programs, and activities at their school. These questions determined whether a policy was in place to increase physical activity (*yes or no*), whether physical education was in the curriculum (*required, available but not required, not available*), whether late-bus service was provided for students participating in extra-curricular activities (*yes or no*), and the number of varsity and intramural sports offered. Varsity sports teams are those that compete with other schools and often require try-outs; intramural sports are usually open to anyone wishing to play and competition occurs within a school. In addition, principals were asked if

their school had a playing field (*yes or no*) or gymnasium/weight room (*yes or no*) and whether these facilities were in good condition. Responses for gym and field condition were grouped to create 3 categories: poor condition (*disagree and strongly disagree*), neutral (*neither agree nor disagree*), and good condition (*agree and strongly agree*). Finally, an additive scale of the cumulative number of supportive recreational features was constructed that considered: having a policy (*yes/no*), having 4+ varsity sports (*yes/no*), having 4+ intramural sports (*yes/no*), presence of a playing field (*yes/no*), having a field in good condition (*yes/no*), and having a gymnasium in good condition (*yes/no*).

Confounders

Variables considered *a priori* as potential confounders were grade, gender, and family socioeconomic status at the individual-level, and school safety, school size, and urban/rural location at the area-level. Students' responses to questions regarding vehicle and computer ownership, bedroom sharing, and holiday travel were used to create a 3-point Family Affluence Scale (*low, medium, high*) which was used as a proxy for socioeconomic status[15] and which is associated with physical activity in Canadian adolescents[16]. Principals were asked to what extent (*not a problem, minor problem, moderate problem, major problem*) the following issues were a problem at their school: classroom disturbances, physical conflicts, weapon possession, drug/alcohol use, vandalism, race/ethnic based conflicts, and verbal abuse of teachers. Responses were combined to obtain an overall dichotomous measure of school safety (*not a problem;*

minor/moderate/major problem). Principals reported the number of students attending their school; schools were divided into low, medium, and high population tertiles. Urban-rural school location was imputed from Statistics Canada's Census Metropolitan Area data and based on school postal code. Urban schools were those located in urban cores, urban fringes, secondary urban cores, and urban areas outside metropolitan areas; rural schools were those located in rural fringes or rural areas outside metropolitan areas[17].

Analysis

Statistical analyses were performed in SAS version 9.1 (SAS, Cary NC). The first set of analyses examined associations between the potential confounders and physical activity at school during *class-time* and *free-time*, respectively. Each covariate was entered into a multilevel logistic regression model. Covariates that were significantly ($p<0.05$) associated with the physical activity outcomes were retained in all subsequent models to account for confounding. Correlation between the school-level characteristics/policies was explored using Spearman rank correlations and chi-square tests.

Next, relationships between school recreational characteristics and physical activity outcomes were examined. Multilevel logistic regression was applied to account for the clustered and hierarchical nature of the data. Because physical activity is not a rare outcome, the odds ratios (OR) obtained from logistic regression do not approximate relative risk[18]. Therefore, rate ratios (RR) were derived by adjusting OR by the

proportion of the outcome in the referent groups (P_0) as follows: RR=OR/((1-P_0) + (P_0 x OR))[18].

The SAS GLIMMIX procedure was used to fit generalized linear mixed models with a binomial distribution and logit link. The method of estimation was a restricted maximum likelihood procedure. All multilevel logistic regression models employed a Newton-Raphson with ridging technique to aid convergence. First, models were fit to test whether there were random slopes for grade, gender, and family affluence to determine whether the effects of these characteristics differed between schools. No significant random slopes were detected for either physical activity outcome. Second, because cross-level interactions between the school-level variables and grade, gender, and family affluence were suspected *a priori*, these cross-level interactions were tested while controlling for significant covariates. For variables with a significant interaction by at least one of the variables, subgroup analyses for each of these variables were performed and the statistical significance of the interaction presented.

Results

The distribution of the student participants according to demographic characteristics is shown in Table 1. Overall, 55.1% and 49.3% of students reported being physically active for ≥2 hours/week during class-time and free-time at school, respectively. Table 2 presents the distribution of schools according to the recreational features.

Confounders

Gender, grade, and family affluence were associated with physical activity at school (Table 1). School safety and school population size, but not urban/rural school location, were associated with physically activity (Table 3). Therefore, all models of the association between school characteristics/policies and physical activity included gender, grade, family affluence, school safety, and school population as covariates.

Overall, the school characteristics were not strongly correlated with each other, with correlation coefficients ranging from –0.17 to 0.23 and the majority near zero (Appendix B – Table A & B). Due to the lack of correlations between school-level variables, multivariate relationships that simultaneously considered the individual school-level variables were not explored.

School characteristics and physical activity

Significant interactions for at least one of the individual-level variables (gender, grade, family affluence) were observed for the majority of the school characteristics and physical activity associations. Therefore, results are presented within gender, age, and family affluence subcategories (Tables 4 and 5).

Class-time physical activity (Table 4). The majority of the school characteristics were not significantly associated with class-time physical activity; as such only significant results are discussed. Having a playing field was positively associated with boys' class-time physical activity (RR: 1.29; 95% CI: 1.12-1.44). Junior high school students at schools with gyms in poor condition were 1.28 (95% CI: 1.06-1.46) times

more likely to be physical activity compared to students at schools with gyms in neutral condition. Students at high schools with 4 or more intramural sports were 1.23 (95% CI: 0.92-1.52) times more likely to be physically active during class-time than students at high schools with no intramural sports.

Free-time physical activity (Table 5). Elementary school students attending schools with a policy to increase physical activity were 1.20 (95% CI: 0.99-1.41) times more likely to be physically active during their free-time compared to students attending schools without such a policy; no association was observed for older youth. Having varsity sports was significantly related to elementary students' free-time physical activity. Having a playing field was associated with boys' (RR: 1.21; 95% CI: 1.04-1.37), but not girls', free-time physical activity. Conversely, the playing field condition was important for girls but not boys. Boys at schools with gymnasia in poor and good condition were approximately 25% more likely to be physically active during their free-time compared to boys at schools with gymnasia in neutral condition; gymnasium condition was not important for girls.

Cumulative effect of school characteristics on physical activity

The cumulative effect of supportive recreational facilities, opportunities, and policies was more pronounced than the effect of the individual characteristics. Increased number of supportive features was associated with increased participation in class-time (Table 4) and free-time (Table 5) physical activity at school. In particular, this scale was most strongly related to class-time physical activity among high school boys

(p_{trend}=0.004); boys' participation in class-time physical activity was 53% higher in high schools with 5-to-6 recreational features compared to schools with none or 1 feature (Figure 1). The effect of increased number of recreational features was most strongly related to high school girls' free-time physical activity (p_{trend}=0.049). Girls at high schools with several features (5-6) were 62% more likely to be physically active than girls at schools with few features (0-1) (Figure 1).

Discussion

The cumulative effect of school recreational features on students' physical activity was greater than the modest associations observed between individual characteristics and adolescents' physical activity at school. In general, most associations varied between boys and girls, students' from different grades, and students' of varying family affluence. Taken together, the findings suggest that the overall school recreational environment may be more important in promoting physical activity than any single policy, facility, or recreational opportunity.

Few school characteristics were associated with adolescents' class-time physical activity. Because students in grades 6-9 are required to take physical education in most school boards in Canada, one might expect little variability in the outcome. However, this was not the case as the proportion of students participating in at least 2 hours/week of class-time physical activity varied from 23% to 85% across the schools studied. This variability was not well explained by the school characteristics under consideration, nor by age and gender, well-established individual-level determinants of overall physical

activity. This suggests that other variables not considered here might be important in determining students' class-time physical activity.

Class-time physical activity occurs under the direction and supervision of a physical education teacher, with students sometimes having little choice in the sports and activities taught and their intensity. As such, characteristics of the school may not be as important as characteristics of the physical education classes themselves. Speculatively, characteristics of teachers (e.g. training, class involvement), class sizes, equipment availability and quality, and the specific modules in the curriculum may be important in determining class-time physical activity. Consistent with this hypothesis, McKenzie et al.[11] demonstrated that grade 6 girls' activity during physical education classes varied depending on characteristics of the class; girls spent a larger proportion of their time engaging in physical activity during fitness activities (as compared to skill drills and game play), during co-ed classes, and during outdoor classes[11].

Unlike younger students who must take physical education, older youth (e.g. those in grade 10) may choose to take physical education and as such have more control over the physical activity they achieve during class-time. The fact that the composite scale describing the overall school recreational environment was most strongly related to high school students physical activity suggests that the school characteristics considered may be important in encouraging older students to take physical education. Unfortunately this possibility could not be explored since information on participants' enrolment in physical education was not available.

Compared to class-time physical activity, the amount of free-time physical activity in which students engage is highly self-regulated. Interestingly, several school characteristics were related to this outcome. Having a greater number of varsity sports was a predictor of student free-time physical activity, particularly for girls and students in lower grades. However, the temporality of the association should be interpreted with caution; it is plausible that schools might provide more varsity sports to accommodate the interests of a more active student body. Likewise, temporality could potentially explain the counterintuitive finding that poor field and gym condition were associated with increased free-time physical activity in some subgroups; although good field and gym condition may drive students to use these facilities, increased use of the facilities may cause them to deteriorate. Interestingly, presence of a field but not its condition was related to boys' physical activity; this may suggest that aesthetics are important for females but not males.

The composite scale describing overall recreational environment was more strongly related to free-time physical activity than any one individual characteristic. Similarly, Fein et al[10] found that perceived availability and importance of the overall school recreational environment was correlated with overall energy expenditure among rural high school students living in Alberta, Canada. Although the association was weak, it is possible that through use of a context-specific measure of physical activity (e.g. activity at school) stronger associations may have been detected. Overall, only a few methodologically dissimilar studies have examined the effects of varying aspects of the

school environment on individuals' school time physical activity[9-12]; as such there is a lack of comparable findings.

There is often a tendency in population and public health research to disregard the importance of small effect sizes. However, the importance of a health determinant should consider both the magnitude of effect and the prevalence of the exposure. Schools are ubiquitous and as such school characteristics may be particularly important in influencing physical activity rates in students. In addition, although each individual school characteristic was weakly associated with physical activity, their combined effect was greater, as was demonstrated by a 1.5-1.6 fold increase in physical activity among high school students with the most recreational features (~30% of schools). This suggests that increasing the number of schools that provide both facilities and opportunities for recreation may be effective in increasing physical activity rates among adolescents.

The present study examined a large, representative sample of Canadian youth. Since adolescent physical activity rates and educational systems are likely similar across the United States and Europe, the findings of this study may be largely generalizable to other industrialized countries. The current study is, however, limited by its cross-sectional design. In addition, the risk estimates may have been biased towards the null due to the self-reported nature of the exposure and outcome measures. It is likely that study participants over-reported their physical activity due to social desirability[19] independent of the school environment, leading to non-differential misclassification of the physical activity outcomes. In addition, dichotomous physical activity outcomes

were derived from ordinal responses to physical activity questions in order to make results more easily interpretable. This may have diluted effect estimates, as individuals with physical activity levels around the cut-point of 2 hours per week may have been similar in their exposure experience or misclassified. In addition there are no clear guidelines for optimal levels of physical activity during school hours; as such this dichotomy is somewhat arbitrary. Finally, although the overall sample size provided power to detect rate ratios as small as 1.2, subgroup analyses may have been underpowered.

In summary, the findings of this study suggest that aspects of the school recreational environment are modestly related to adolescents' physical activity at school, particularly that which occurs during free-time. Taken together, the cumulative effect of the overall state of the school recreational environment may be more important than any one characteristic individually. Identification of school features that promote physical activity may inform educational policy and support funding of recreational opportunities.

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Table 1. Distribution of the student sample (n=7638) according to individual-level variables and the association between the individual-level variables and physical activity at school during class time and free time

Variable	N	%	Physically active at least 2 hours/week during *class- time* **RR (95% CI)**	Physically active at least 2 hours/week during *free- time* **RR (95% CI)**
Gender				
Male	3652	47.8	1.00 (referent)	1.00 (referent)
Female	3985	52.2	0.95 (0.91-0.99)	0.80 (0.76-0.84)
Grade				
Elementary (Gr. 6)	1442	18.9	1.00 (referent)	1.00 (referent)
Junior (Gr. 7-8)	2954	38.7	1.07 (1.01-1.13)	0.91 (0.86-0.96)
High School (Gr.9-10)	3242	42.4	0.92 (0.87-0.98)	0.81 (0.77-0.86)
Family Affluence				
Low	665	9.0	1.00 (referent)	1.00 (referent)
Medium/High	6704	91.0	1.20 (1.10-1.30)	1.20 (1.10-1.32)
Class-time Physical Activity				
None	894	11.7	N/A	Referent
½ hour per week	900	11.8		0.90 (0.77-1.05)
1 hour per week	1640	21.5		1.22 (1.08-1.38)
2 hours per week	1284	16.8		1.81 (1.60-2.03)
3 hours per week	1030	13.5		2.26 (2.02-2.54)
4+ hours per week	1890	24.8		2.70 (2.43-3.01)
Free-time Physical Activity				
None	1293	16.9	Referent	N/A
½ hour per week	1338	17.5	1.25 (1.12-1.39)	
1 hour per week	1241	16.2	1.59 (1.44-1.76)	
2 hours per week	932	12.2	2.13 (1.93-2.35)	
3 hours per week	812	10.6	2.41 (2.19-2.65)	
4+ hours per week	2022	26.5	2.57 (2.34-2.81)	

RR (95% CI) = Rate ratio (95% confidence interval)

Table 2. Distribution of the study schools (n=154) according to school-level variables

School characteristic	N	%
Has a policy to increase physical activity	99	64.7
Physical education required in the curriculum	150	97.4
Has late bus service for extracurricular activities	12	7.8
Has a playing field	141	92.2
Has a gymnasium	143	93.5
Field condition		
Poor	32	21.2
Neutral	19	12.6
Good	100	66.2
Gymnasium condition		
Poor	15	9.9
Neutral	10	6.6
Good	126	83.4
Number of intramural sports offered		
None	34	22.1
1-3	83	53.9
4+	37	24.0
Number of varsity sports offered		
None	17	11.1
1-3	66	43.1
4+	70	45.8
Number of recreational features		
0-1	4	2.8
2	16	11.0
3	32	22.1
4	51	35.2
5-6	42	28.9

Table 3. Bivariate associations between potential school-level confounders and students' physical activity during free-time and class-time at school

Variable	N (schools)	%	Physically active at least 2 hours/week during *class time* RR (95% CI)	Physically active at least 2 hours/week during *free time* RR (95% CI)
Urban/rural school location				
Rural	23	15.0	1.00 (referent)	1.00 (referent)
Urban	130	85.0	1.06 (0.93-1.19)	0.94 (0.82-1.07)
School size				
Lowest tertile	51	33.1	1.00 (referent)	1.00 (referent)
Middle tertile	52	33.8	0.98 (0.88-1.07)	1.00 (0.90-1.09)
Highest tertile	51	33.1	0.92 (0.81-1.02)	**0.82 (0.72-0.93)**
School safety				
Not a problem	114	87.0	1.00 (referent)	1.00 (referent)
Minor/moderate/major problem	37	13.2	**0.91 (0.82-1.00)**	**0.88 (0.78-0.98)**

RR (95%CI) = Rate ratio (95% confidence interval)

Table 4. Associations between school characteristics and being physically active for 2 or more hours per week at school during class-time by gender, grade and family affluence

	GENDER [a]			GRADE [b]				FAMILY AFFLUENCE [c]		
	Male (n=3652) RR (95% C.I)	Female (n=3985) RR (95% C.I)	p*	Elementary (n=1442) RR (95% C.I)	Junior (n=2954) RR (95% C.I)	High School (n=3242) RR (95% C.I)	p*	Low (n=665) RR (95% C.I)	Medium/High (n=6704) RR (95% C.I)	p*
Has a policy	1.07 (0.97-1.17)	1.10 (0.99-1.22)	0.220	1.00 (0.82-1.17)	1.06 (0.95-1.16)	**1.18 (1.02-1.34)**	0.076	1.07 (0.85-1.30)	**1.10 (1.00-1.19)**	0.395
Playing field	**1.29 (1.13-1.44)**	0.99 (0.84-1.12)	0.001	1.22 (0.93-1.49)	1.09 (0.93-1.23)	1.12 (0.90-1.31)	0.266	1.03 (0.72-1.34)	1.13 (0.99-1.25)	0.104
Gymnasium	0.94 (0.78-1.10)	1.09 (0.88-1.29)	0.059	0.93 (0.75-1.11)	1.17 (0.99-1.33)	0.92 (0.50-1.36)	0.028	0.89 (0.57-1.23)	1.02 (0.86-1.18)	0.267
Field condition										
Poor	0.95 (0.78-1.11)	0.92 (0.74-1.09)	0.042	1.02 (0.77-1.29)	1.00 (0.84-1.16)	0.81 (0.57-1.07)	0.005	0.74 (0.48-1.03)	0.97 (0.82-1.12)	0.017
Neutral	1.00 (referent)	1.00 (referent)		1.00 (referent)	1.00 (referent)	1.00 (referent)		1.00 (referent)	1.00 (referent)	
Good	1.04 (0.90-1.17)	0.97 (0.82-1.12)		1.17 (0.94-1.39)	0.97 (0.83-1.10)	0.95 (0.72-1.17)		0.81 (0.59-1.05)	1.04 (0.91-1.16)	
Gym condition										
Poor	0.92 (0.75-1.08)	1.18 (0.91-1.43)	0.044	0.91 (0.61-1.22)	**1.28 (1.06-1.46)**	1.13 (0.63-1.60)	0.002	0.91 (0.52-1.30)	1.08 (0.87-1.29)	0.114
Neutral	1.00 (referent)	1.00 (referent)		1.00 (referent)	1.00 (referent)	1.00 (referent)		1.00 (referent)	1.00 (referent)	
Good	0.97 (0.83-1.11)	1.17 (0.95-1.37)		1.09 (0.83-1.34)	1.11 (0.94-1.26)	1.23 (0.77-1.64)		0.89 (0.57-1.22)	1.13 (0.96-1.29)	
Intramural sports										
0	1.00 (referent)	1.00 (referent)	0.019	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.016	1.00 (referent)	1.00 (referent)	0.153
1-3	1.03 (0.91-1.15)	1.07 (0.94-1.21)		1.06 (0.90-1.22)	0.99 (0.86-1.11)	1.16 (0.91-1.42)		1.09 (0.81-1.39)	1.03 (0.92-1.13)	
4+	1.12 (0.99-1.25)	1.07 (0.92-1.22)		1.15 (0.98-1.32)	1.01 (0.87-1.14)	1.23 (0.92-1.52)		1.20 (0.87-1.53)	1.08 (0.96-1.20)	
Varsity sports										
0	1.00 (referent)	1.00 (referent)	0.080	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.067	1.00 (referent)	1.00 (referent)	0.124
1-3	1.03 (0.86-1.18)	0.92 (0.74-1.09)		0.87 (0.71-1.02)	1.20 (0.95-1.42)	1.02 (0.64-1.39)		1.24 (0.82-1.67)	0.96 (0.82-1.10)	
4+	1.02 (0.85-1.19)	0.94 (0.76-1.12)		0.86 (0.68-1.03)	**1.25 (1.00-1.47)**	1.04 (0.68-1.38)		1.23 (0.80-1.68)	0.96 (0.82-1.11)	

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Number of recreational features										
0-1	1.00 (referent)	1.00 (referent)	0.019	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.120	1.00 (referent)	1.00 (referent)	0.003
2	1.29 (0.99-1.54)	1.08 (0.80-1.29)		1.21 (0.72-1.67)	1.08 (0.81-1.29)	1.29 (0.88-1.59)		0.91 (0.43-1.47)	1.20 (0.96-1.40)	
3	1.22 (0.94-1.47)	1.05 (0.79-1.26)		1.17 (0.71-1.60)	1.06 (0.80-1.26)	1.27 (0.89-1.56)		1.16 (0.65-1.64)	1.14 (0.90-1.34)	
4	**1.32 (1.05-1.54)**	1.06 (0.81-1.26)		1.21 (0.75-1.63)	1.07 (0.82-1.26)	1.28 (0.92-1.56)		1.11 (0.63-1.59)	1.18 (0.96-1.37)	
5-6	**1.37 (1.11-1.59)**	1.11 (0.86-1.30)		1.37 (0.90-1.74)	1.07 (0.82-1.27)	**1.42 (1.07-1.65)**		1.01 (0.53-1.51)	**1.25 (1.03-1.42)**	

RR (95%CI) = Rate ratio (95% confidence interval).

* p value for interaction

[a] RR were adjusted for grade, family affluence, school population size, school safety

[b] RR were adjusted for gender, family affluence, school population size, school safety

[c] RR were adjusted for grade, gender, school population size, school safety

Table 5. Associations between school characteristics and being physically active for 2 or more hours per week at school during free-time by gender, grade and family affluence

	GENDER [a]			GRADE [b]				FAMILY AFFLUENCE [c]		
	Male (n=3652) RR (95% C.I)	Female (n=3985) RR (95% C.I)	p*	Elementary (n=1442) RR (95% C.I)	Junior (n=2954) RR (95% C.I)	High School (n=3242) RR (95% C.I)	p*	Low (n=665) RR (95% C.I)	Medium/High (n=6704) RR (95% C.I)	p*
Has a policy	0.98 (0.88-1.08)	1.09 (0.95-1.24)	0.002	1.20 (0.99-1.41)	1.00 (0.85-1.16)	0.98 (0.85-1.12)	0.049	1.01 (0.78-1.26)	1.03 (0.92-1.13)	0.809
Playing field	1.21 (1.04-1.37)	1.06 (0.84-1.27)	0.043	1.14 (0.84-1.43)	1.13 (0.90-1.36)	1.09 (0.87-1.31)	0.121	1.12 (0.73-1.47)	0.89 (0.60-1.20)	0.023
Gymnasium	1.11 (0.92-1.28)	1.00 (0.78-1.24)	0.080	0.95 (0.76-1.13)	1.16 (0.91-1.40)	1.26 (0.78-1.80)	0.368	1.26 (0.81-1.76)	1.18 (0.85-1.47)	0.631
Field condition										
Poor	1.07 (0.90-1.25)	**1.40 (1.11-1.70)**	0.001	1.19 (0.89-1.48)	1.21 (0.95-1.47)	1.17 (0.89-1.46)	0.005	1.17 (0.77-1.62)	**1.21 (1.02-1.41)**	0.182
Neutral	1.00 (referent)	1.00 (referent)		1.00 (referent)	1.00 (referent)	1.00 (referent)		1.00 (referent)	1.00 (referent)	
Good	1.09 (0.94-1.23)	**1.43 (1.18-1.69)**		**1.30 (1.03-1.54)**	1.12 (0.90-1.35)	1.22 (0.97-1.47)		1.09 (0.77-1.46)	**1.23 (1.06-1.40**	
Gym condition										
Poor	**1.23 (1.07-1.38)**	0.92 (0.65-1.23)	0.046	0.93 (0.63-1.24)	1.07 (0.78-1.33)	1.31 (0.81-1.84)	0.231	**1.15 (1.01-1.27)**	0.98 (0.75-1.21)	0.010
Neutral	1.00 (referent)	1.00 (referent)		1.00 (referent)	1.00 (referent)	1.00 (referent)		1.00 (referent)	1.00 (referent)	
Good	**1.25 (1.11-1.37)**	0.96 (0.73-1.19)		0.99 (0.73-1.24)	1.00 (0.79-1.20)	1.38 (0.92-1.85)		**1.16 (1.04-1.26)**	1.06 (0.88-1.24)	
Intramural sports										
0	1.00 (referent)	1.00 (referent)	0.051	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.124	1.00 (referent)	1.00 (referent)	0.165
1-3	0.97 (0.85-1.08)	0.99 (0.84-1.14)		0.96 (0.80-1.11)	0.88 (0.73-1.04)	1.10 (0.90-1.29)		1.07 (0.77-1.40)	0.97 (0.86-1.08)	
4+	1.02 (0.89-1.14)	1.01 (0.85-1.18)		1.14 (0.97-1.30)	0.92 (0.74-1.09)	1.04 (0.81-1.27)		1.19 (0.84-1.57)	1.00 (0.88-1.13)	
Varsity sports										
0	1.00 (referent)	1.00 (referent)	0.052	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.007	1.00 (referent)	1.00 (referent)	0.232
1-3	1.18 (0.99-1.35)	1.22 (0.98-1.47)		**1.25 (1.03-1.47)**	1.13 (0.82-1.43)	1.08 (0.73-1.45)		1.27 (0.82-1.76)	**1.19 (1.01-1.37)**	
4+	**1.21 (1.02-1.39)**	**1.27 (1.02-1.53)**		**1.31 (1.06-1.55)**	1.25 (0.93-1.54)	1.13 (0.79-1.48)		1.31 (0.84-1.82)	**1.23 (1.04-1.40)**	

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Number of recreational features										
0-1	1.00 (referent)	1.00 (referent)	0.001	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.004	1.00 (referent)	1.00 (referent)	0.030
2	1.21 (0.88-1.51)	0.91 (0.56-1.28)		0.85 (0.45-1.28)	1.03 (0.61-1.44)	1.18 (0.77-1.59)		0.66 (0.33-1.05)	1.07 (0.76-1.38)	
3	1.22 (0.92-1.50)	0.95 (0.62-1.30)		0.90 (0.52-1.30)	1.16 (0.75-1.52)	1.21 (0.83-1.57)		0.62 (0.32-0.99)	1.13 (0.83-1.41)	
4	**1.30 (1.01-1.55)**	1.02 (0.69-1.35)		1.09 (0.68-1.45)	1.09 (0.69-1.45)	1.21 (0.85-1.56)		0.76 (0.43-1.10)	1.19 (0.90-1.46)	
5-6	1.26 (0.97-1.53)	1.09 (0.75-1.42)		1.11 (0.70-1.47)	1.12 (0.71-1.48)	1.28 (0.90-1.64)		0.71 (0.38-1.06)	1.20 (0.91-1.48)	

RR (95%CI) = Risk ratio (95% confidence interval). RR were adjusted for school size, school safety, and gender, grade, and family affluence, where appropriate

* p value for interaction

[a] RR were adjusted for grade, family affluence, school population size, school safety

[b] RR were adjusted for gender, family affluence, school population size, school safety

[c] RR were adjusted for grade, gender, school population size, school safety

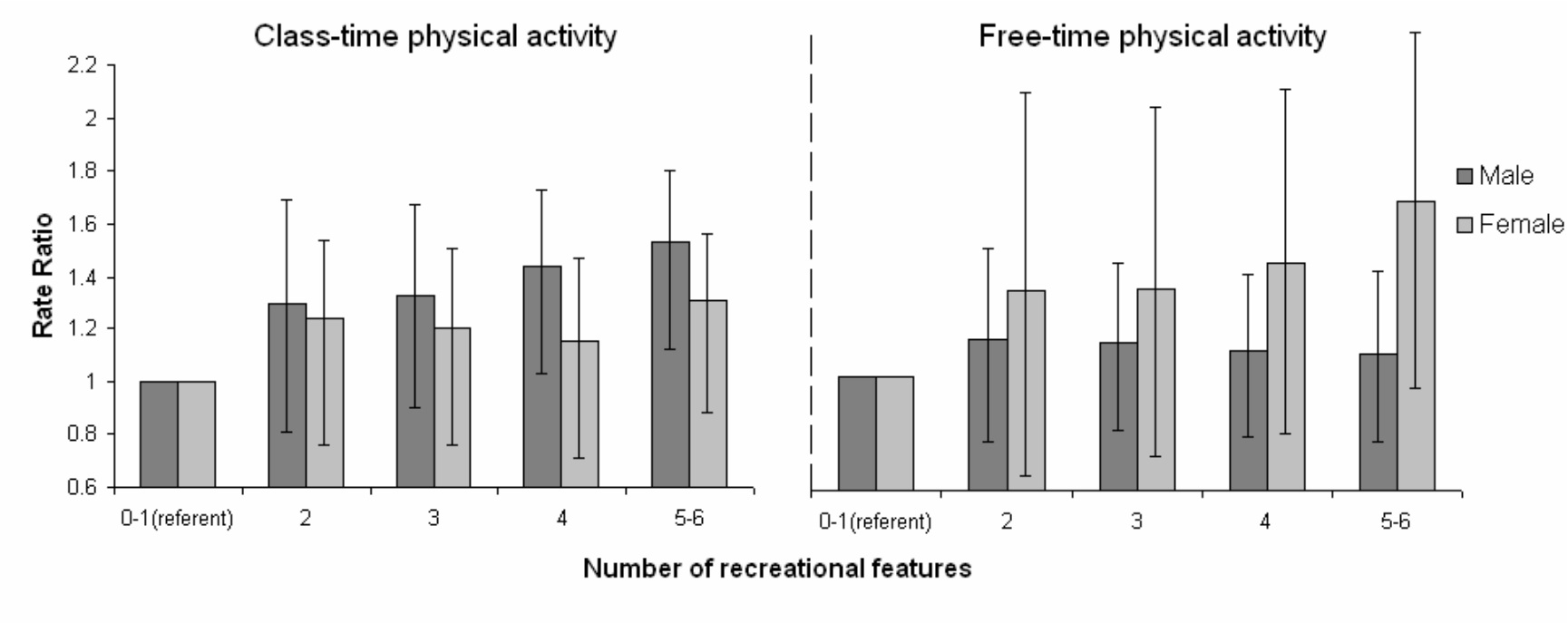

Figure 1. Effect of composite scale of school facilities and opportunities on class-time and free-time physical activity among high school students (grade 9 and 10) by gender

Chapter 4
Manuscript 2: Perceptions of neighbourhood safety, not recreational facilities, are associated with adolescent physical activity

This manuscript conforms to the specifications for submission to the peer-reviewed journal *Pediatrics.*

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Short title: Safety associated with physical activity in youth

Abbreviations: HBSC - Health Behaviour in School-Aged Children Survey
SES- Socioeconomic status
OR – odds ratio
RR – rate ratio
CI – confidence interval

Keywords: adolescent health, physical fitness, environmental aspects, environment and public health, epidemiology, multilevel modelling

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Abstract

Objective: To examine the importance of neighbourhood safety and availability of parks and recreational facilities as potential determinants of adolescent physical activity.

Patients and Methods: Data from 9114 Canadians in grades 6-10 were obtained from the 2006 Health Behaviour in School-Aged Children Survey. Questions that captured student perceptions of neighbourhood safety were used to create a composite scale of perceived neighbourhood safety. Schools were grouped into quintiles based on the mean of the perceived safety scale, used as a proxy for peer perceptions. The number of parks and recreational facilities within a 5 km radius of schools was abstracted from a geographical information system. Multi-level logistic regression was employed to quantify associations between perceived and objective neighbourhood characteristics with physical activity.

Results: Moderate gradients in physical activity were observed according to individual and group perceptions of neighbourhood safety. Boys and girls with the highest perceptions of safety were 1.30 (95% CI: 1.16-1.44) and 1.43 (95% CI: 1.24-1.63) times more likely to be physically active, respectively, than those with the lowest perceptions of safety. Group perceptions of safety were important for elementary school students and students living in large cities. Compared to elementary school youth whose peers perceived the neighbourhood as least safe, students in higher quintiles (2^{nd} through 5^{th}) were 1.20, 1.36, 1.42, and 1.55 times more likely to be physically active (p_{trend}=0.005). Increased numbers of recreational features were not related to adolescents' physical activity, regardless of urban/rural location and perceptions of safety.

Conclusions: Individual and group perceptions of neighbourhood safety were modestly associated with adolescents' physical activity participation, whereas availability of parks and recreational facilities was not. Improving both perceptions of safety as well as actual safety may be effective in increasing physical activity participation among youth.

Introduction

A cross-national study of 11-15 year olds conducted in 34 countries revealed that less than 50% of youth within each country achieved the recommended level of moderate-to-vigorous physical activity[1]. In addition to characteristics of individuals and their families, characteristics of the built and social environment are believed to contribute to physical activity participation[2]. Most recent research has focused on aspects of the built environment that may promote or hinder physical activity among young people, including the availability of parks and recreational facilities within an individuals' neighborhood[3-11]. A similar number of studies have considered both perceived and tangible measures of safety[4-7;12-16]. Although features of the built and social environment are correlated with adolescents' physical activity, it is not clear if these features are independent determinants of physical activity and if so, which are the most salient risk factors. In addition, individual and group perceptions of neighbourhood safety may modify individuals' decisions to use neighbourhood facilities alone or socially.

The purpose of the current study was to examine the independent effects of 1) individual and group perceptions of neighbourhood safety, and 2) availability of parks and recreational facilities on physical activity participation in youth. It was anticipated that availability of recreational features might only be important in areas perceived safe by students. Identification of neighbourhood characteristics that independently promote physical activity may inform population-level interventions or environmental planning aimed at improving current obesogenic environments.

Subjects and Methods

Survey Design

Data from the cross-sectional, nationally representative 2005/06 Canadian *Health Behaviour in School-Aged Children Survey (HBSC)* were analyzed. Information on demographic, psychosocial characteristics, health behaviours, and health outcomes was collected from students in grades 6 through 10 in 188 publicly funded schools from across Canada. The *HBSC* excluded youth attending private, special-needs, and home schools as well as institutionalized, incarcerated, and homeless youth[17]. Together, these excluded groups represent ~9% of this age group in Canada[18]. Institutional consent was solicited from school boards and individual schools; participating students provided parental and individual consent. The *HBSC* is conducted in collaboration with the World Health Organization, and the Canadian *HBSC* followed the established international protocol[17]. The *HBSC* survey is designed to be self-weighting and uses a cluster sampling design, with randomly selected classrooms reflecting the provincial distributions of schools by size, location, language, and religion[17].

The *HBSC* collected information from 9672 children in grades 6 through 10 in 188 schools. Of these, 5 schools were not included because neighbourhood-level information could not be linked to student information, leaving 9199 students in 183 schools. Of these, 85 students were excluded due to incomplete physical activity information, leaving 9114 (94.2%) students from 182 (97.3%) schools available for analysis.

Outcome: physical activity outside of school

The outcome of interest was participation in moderate-to-vigorous physical activity outside of school. Students provided responses to the question: "outside of school hours, how many hours a week do you usually exercise in your free time so much that you get out of breath or sweat?" There were six response categories: "none", "about ½ hour", "about 1 hour", "about 2 to 3 hours", "about 4 to 6 hours" and "7 or more hours". Ordinal responses were grouped to create a dichotomous outcome (≥ 4 hours/week vs. < 4 hours/week) that would be more easily interpretable for health policy[19]. Total physical activity is composed of activities that occur inside and outside of school; as such a threshold of 4 hours per week outside of school is assumed to be consistent with the physical activity guideline for 60 minutes of moderate-to-vigorous physical activity on most if not all days of the week[20]. This threshold was expected to be met by 45% of students, consistent with the overall rate of physical activity participation in Canadian youth[1].

Key exposures

Individual perceptions of neighbourhood safety

Students responded to three statements/questions regarding the safety of their neighbourhood: "I feel safe in the area where I live" (*always, most of the time, sometimes, rarely or never),* "do you think that the area in which you live is a good place to live? (*it's really good, it's good, it's ok, it's not very good/ it's not good at all),* and "it is safe for younger children to play outside during the day" (*strongly agree, agree,*

neither agree nor disagree, disagree/strongly disagree). Principal component factor analysis revealed agreement between these 3 variables; factor loadings were 0.84, 0.85, and 0.66, respectively. The Cronbach's alpha coefficient indicated a reasonable level of internal consistency (0.68). These questions were combined with equal weight and then categorized to create a 3-point composite scale of perceived neighbourhood safety (least safe, safe, most safe).

Group perceptions of neighbourhood safety

The group mean of the perceived safety scale was calculated for each school. Schools were then ranked and grouped into quintiles based on the mean of the perceived safety scale. This measure was considered as a social construct capturing peer perceptions of neighbourhood safety.

Neighbourhood parks and recreational facilities

Neighbourhood-level data on parks and recreational facilities were obtained from *CanMap Streetfiles*, a cross-national geographical information system with positionally-accurate geospatial data for schools, parks, trails, and recreational points of interest, in addition to other geographical information[21]. Using ArcGIS software (ESRI, Redlands, CA), participating schools were identified in *CanMap Streetfiles* according to school name and street address. Neighbourhood-level information was subsequently linked to individual-level information from the student participants of the *HBSC*.

A 5-km circular buffer was applied around each school and was considered as a proxy for the residential neighbourhood for the school. Numbers of parks and recreation facilities within this 5-km buffer were counted. Parks included national parks, provincial and territorial parks, and municipal parks/sports fields. Trails included educational, recreational and park trails. The park and trail variables were classified into categories (none, 1-3, 4-19, 20+ per 5 km radius). Types of recreational facilities considered in this analysis were: arenas, community centres, sportsplexes/stadiums, and swimming pools; these were also treated categorically (none, 1, 2-4, 5+ per 5 km radius). Finally, a composite scale that considered the overall neighbourhood recreational environment was constructed by combining ranked scores for each of the park/facilities. Schools were then divided into quintiles based on this composite score.

Potential Covariates

Variables considered *a priori* as potential covariates at the individual-level were: gender, grade, family socioeconomic status, and perceived neighbourhood aesthetics. Neighbourhood-level confounders under consideration were neighbourhood-level socioeconomic status (SES) and geographic location.

Gender and grade were self-reported by students. Students provided responses to questions regarding vehicle and computer ownership, bedroom sharing and holiday travel; these questions were used to create a 3-point Family Affluence Scale (low, medium, high) which is used as a proxy for family socioeconomic status[22] and associated with physical activity in Canadian youth[23]. Students were asked how much litter, broken

glass and garbage was present in their neighbourhood (lots, some, none) and to what extent there were run-down houses and buildings in the neighbourhood (lots, some, none); responses to these questions were used to assess perceived neighbourhood aesthetics.

Area-level socioeconomic status (SES) was obtained from 2001 Canadian Census information using PCensus software[18]. Neighbourhood-level SES was determined by combining ranked scores for median household income, employment rate and the percent of the population with greater than high school education[18]. Schools were then divided into low, medium and high SES tertiles based on this overall score. Geographic location was imputed from Statistics Canada's Census Metropolitan Area data and based on school postal code[18]. Schools were divided into 3 groups: urban schools inside metropolitan areas, urban schools outside metropolitan areas, and rural schools. Urban schools inside metropolitan areas were those located in urban cores, urban fringes, and secondary urban cores, urban schools outside metropolitan areas were considered separately. Rural schools were those located in rural fringes or rural areas outside metropolitan areas[24].

Statistical Analysis

All statistical analyses were performed in SAS version 9.1 (SAS Inc, Carry, NC). In order to determine the relative importance of perceptions of safety and availability of neighbourhood recreational features, multivariate multilevel analyses were performed that simultaneously considered: scales of individual and group perceptions of safety, a

scale of neighbourhood facility availability, and a parsimonious list of covariates that were significantly associated with the study outcome (gender, grade, family affluence, and geographic location). The SAS GLIMMIX procedure was used to fit generalized linear mixed models with a binomial distribution and logit link, in order to account for the clustered and hierarchical nature of the data. The method of estimation was a restricted maximum likelihood procedure. All multilevel logistic regression models employed a Newton-Raphson with ridging technique to aid convergence[25].

Cross-level interactions between the key exposures and grade, gender, and urban location were suspected *a priori.* Upon testing, significant interactions by gender, grade, and location were observed for each of the neighbourhood scales. Therefore, multivariate analyses that simultaneously considered individual and group perceptions of safety and neighbourhood facility availability were performed within gender, age, and location subcategories. In order to test the hypothesis that individual perceptions of safety modify the relationship between facility availability and physical activity, this interaction was tested and results were presented within perception subgroups.

Since physical activity is not a rare outcome, odds ratios obtained from multilevel logistic regression do not necessarily approximate relative risk[26]. Therefore, rate ratios (RR) and confidence intervals (CI) were derived by adjusting odds ratios obtained from these models by the proportion of the outcome in the unexposed/referent groups (P_0) according to the formula: $RR=OR/((1-P_0) + (P_0 \times OR))$[26].

Results

The distribution of the participants according to individual-level variables is shown in **Table 1**. Overall, 36.9% of students reported being physically active for ≥4 hours/week outside of school. **Table 2** presents the bivariate association between perceptions of safety, availability of facilities and physical activity outside of school. Associations between individual recreational features and physical activity are presented in Appendix D – Tables E, F,G.

Significant interactions by gender, grade, and geographic location were observed for the associations between the key exposures and physical activity outside of school. Therefore, **Table 3** presents results within gender, grade, and geographic location subcategories. **Table 4** presents the interaction between individuals' perceptions of safety and availability of neighbourhood facilities.

Perceptions of Neighbourhood Safety

Individuals' perceptions of safety. As indicated in **Table 3**, individuals' perceptions of neighbourhood safety were associated with participation in physical activity outside of school in all subgroups. Boys and girls with the highest perceptions of safety were 1.30 (95% confidence interval: 1.16-1.44) and 1.43 (1.24-1.63) times more likely to be physically active, respectively, than those with the lowest perceptions of safety. This relationship was stronger in youth living in urban non-metropolitan areas compared to urban metropolitan and rural youth. Urban youth outside metropolitan areas who perceived their neighbourhood as the most safe had physical activity rates that

were 56% higher than the classmates who perceived their neighbourhoods as least safe; increases of approximately 30% were observed for urban metropolitan and rural youth.

Group perceptions of safety. Group perceptions of safety were important for both genders, elementary school students, and students living in large cities (Table 3). Elementary school youth at schools with highest average perceptions of safety were 1.55 (1.17-1.97) times as likely to be physical active compared to those at schools with the lowest group perceptions. Urban metropolitan youth at schools with the highest group perceptions were 1.43 (1.20-1.68) times more likely to be physically active compared to those at schools with the lowest group perceptions; no association was observed among urban non-metropolitan and rural youth.

Availability of neighbourhood recreational features

Individual recreational features. Unexpectedly, unadjusted models revealed weak inverse relationships between the number of parks, arenas, community centres, and sportsplexes/stadiums with physical activity outside of school (Appendix D - Table E). Further adjustment for grade, gender, family affluence, urban location, and perceived safety revealed no consistent relationships between individual parks/facilities features and physical activity among any of the subgroups (Appendix D - Tables F & G)).

Total number of recreational features. Overall, no consistent relationships were observed between availability of recreational facilities and adolescents physical activity. After controlling for perceptions of neighbourhood safety and covariates, the number of recreational features within students' neighbourhoods was not significantly related to

physical activity within any of the subgroups (Table 3). To illustrate, compared to boys living in areas with the fewest recreational features, those living in areas with the most recreational features experienced slightly higher rates of physical activity (1.17, 0.99-1.34); the opposite was true for girls (0.85, 0.69-1.02) (Table 3). The relationship between the total number of recreational features and physical activity was non-significant irrespective of whether the students lived in neighbourhoods they perceived as being safe or unsafe (Table 4).

Discussion

Contrary to the original hypothesis, availability of parks and recreational facilities in school residential neighbourhoods was not associated with physical activity in school-aged youth. This finding was not influenced by individuals' perceptions of safety. Individual and group perceptions of neighbourhood safety were significantly associated with physical activity participation. The major finding is that neighbourhood safety may be more important than availability of recreational facilities in influencing youths' participation in physical activity outside of school.

Several studies have explored associations between access to parks[3-5,8,9] and recreational facilities[4,6-8,10,11] with physical activity participation in youth. These studies consistently suggest that availability of neighbourhood recreational features is weakly associated with a higher physical activity participation in youth. Among studies of neighbourhood safety[3-7,12-16], the majority have observed stronger, although modest,

positive associations between increased neighbourhood safety and physical activity[4-7,12,14-16].

Despite the fact that many of these studies investigated both neighbourhood safety and availability of facilities, only one previous study has simultaneously controlled for each in order to determine their relative importance. Evenson et al.[7] investigated the relative importance of perceptions of safety and perceptions of facility availability among grade 6 girls in 6 states across the U.S. Girls' perceptions of a number of recreational facilities were considered along with girls' perceptions of crime, traffic, street lighting, whether they felt it was safe to walk and jog outdoors, and whether pedestrians were visible at night. Street lighting, traffic, walking trails and access to facilities were independently associated with girls' self-reported physical activity outside of school. Thus, both facilities and safety were independent predictors of physical activity participation. These findings are contrary to those of the current study in which individual perceptions of safety, but not neighbourhood recreational facilities, were related to physical activity. The current study is the first to consider the relative importance of safety and availability of facilities among both boys and girls.

In addition to considering the effects of individuals' perceptions of safety, the current study also investigated the importance of these perceptions at the school-level. Group perceptions of neighbourhood safety were important for younger youth. Speculatively, this may be the result of differences in how younger youth engage in physical activity compared to older adolescents. It is possible that younger youth are more likely than their older counterparts to participate in more spontaneous outdoor

activity with their friends. In such a case, peer perceptions of safety may influence younger people's outdoor physical activity irrespective of their own feelings. Older youth may be more likely to be physically active alone (for example walking and jogging alone), in which case only their personal opinions of their neighbourhood would be influential.

Limitations of this research warrant comment. First, due to the cross-sectional design of the *HBSC*, the temporality of observed relationships could not be established; it is plausible that individuals' physical activity behaviour might influence their perceptions of safety through increased exposure to the environment, rather than perceptions influencing physical activity. Second, students often over-report their physical activity due to social desirability[27]; this misclassification would likely be independent of characteristics of the neighbourhood environment and as such may have biased effect estimates towards the null. In addition, dichotomous physical activity outcomes were derived from ordinal responses to physical activity questions in order to make results more easily interpretable. This may have diluted effect estimates, as individuals with physical activity levels around the cut-point of 2 hours per week may have been similar in their exposure experience or misclassified. In addition there are no clear guidelines for optimal levels of physical activity during school hours; as such this dichotomy is somewhat arbitrary. Third, it would have been ideal to measure residential neighbourhoods using buffers constructed around individuals' homes; this was not possible since the *HBSC* is restricted from collecting information on student home addresses for reasons of confidentiality. It is possible that through use of a 5 km buffer

around schools, neighbourhood characteristics may have been ascribed to students who in fact do not live within these radii. Finally, no standard method exists for assessment of neighbourhood environments. Thus, it was unclear which type of buffer should be used (radial versus street network buffers) and what radial distance around schools would be appropriate in capturing the residential neighbourhood of schools. Circular buffers do not consider physical barriers (e.g. freeways, railways, rivers) that might make locations inaccessible[28]. It also is unclear what radial distance is relevant for youth[28]. It is possible that through use of another radial distance different results may have been observed. Stronger observed effects of safety might be attributable to students' perceptions providing a more accurate measure compared with the available measures of facility availability. Lastly, there is a potential for neighbourhood-level associations to be residually confounded by variables not captured in this research, namely street-connectivity. Street-connectivity (i.e. the density and connectedness of roads) may influence ease of walking and other outdoor activities[29] and may also be associated road safety and the number of parks and facilities in neighbourhoods.

Longitudinal analyses are required to establish whether perceptions of safety are true determinants of students' physical activity. Although perceptions of overall safety were associated with youths' physical activity, it is unclear what components of neighbourhood safety are important determinants of adolescent physical activity. In addition, it may be important to understand the extent to which perceptions of safety correspond to the objective environment in order to plan population-based interventions. Future studies should consider whether the accessibility, affordability and/or quality of

recreational features are more important than the number of features. Development of a standard approach to measuring the built environment and physical activity in youth would also improve comparability between studies.

Children and youth today spend less time in outdoor activities compared with previous generations[30]. This is in part attributable to increased individual and parental concerns about "stranger danger" and road safety[31]. Fear of strangers may be a particularly salient factor, although potentially unrelated to actual frequency of crime against youth by strangers[31]. It is estimated that only 115 non-family stereotypical child abductions (those that involve removal of the child for the purposes of ransom, assault or murder) occurred in the United States in 1999[32,33]. To put this issue into perspective, the *UNICEF Report from Rich Nations* concluded that traffic injuries were the leading cause of fatal injury among children in developed countries, and that the majority of these children were pedestrians[34]; in the United States, childhood pedestrian injury accounted for 583 deaths and 33,571 non-fatal serious injuries in 2004 and 2005, respectively[35].

Optimizing the safety of neighbourhoods and increasing individuals' perception of safety may both be effective in promoting outdoor physical activity among youth. This might involve tangible improvement to roads and facilities or interventions that promote greater social interaction and cohesion among community members. The latter could lead to better social environments for young people and indirectly lead to better rates of physical activity. Increasing the number of parks and facilities available to youth may not be effective in promoting physical activity.

Conclusion

In summary, individual and group perceptions of neighbourhood safety were modestly associated with adolescents' physical activity participation, whereas availability of parks and recreational facilities was not. Improving perceptions of safety may be effective in increasing physical activity participation among youth.

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Table 1. Characteristics of the student sample (n=9114) according to individual-level variables and their bivariate association with physical activity outside of school

	Distribution of sample		Physically active outside of school	
	N	%	%	Unadjusted RR (95% CI)
Demographic characteristics				
Gender				
Male	4322	47.4	43.2	1.00 (Referent)
Female	4791	52.6	31.1	0.72 (0.68-0.76)
Grade				
6	1661	18.2	35.5	1.00 (Referent)
7	1717	18.8	34.4	0.97 (0.88-1.06)
8	1830	20.1	37.0	1.04 (0.96-1.14)
9	2093	23.0	37.9	1.07 (0.98-1.16)
10	1813	20.0	39.1	1.10 (1.01-1.20)
Family affluence				
Low	804	9.2	27.0	1.00 (Referent)
Medium	3480	39.7	32.8	1.21 (1.07-1.37)
High	4491	51.1	41.8	1.55 (1.38-1.74)
Physical activity outside of school				
None	515	5.6	N/A	N/A
½-1 hour	2824	31.0		
2-3 hours	2415	26.5		
4-6 hours	1860	20.4		
7+ hours	1500	16.5		

RR (95%CI) = rate ratio (95% confidence interval)

Table 2 Bivariate association between perceptions of safety, availability of facilities and physical activity outside of school.

Facilities within 5 km	Distribution of sample		Physically active outside of school		
			%	Unadjusted RR (95% CI)	*P trend*
Individual perceptions of safety scale	**N** (individuals)	**%**			
1 (least safe)	1859	21.3	29.6	1.00 (referent)	
2	5073	58.2	36.6	1.24 (1.44-1.34)	
3 (most safe)	1773	20.4	45.0	1.52 (1.39-1.65)	<0.001
Group perceptions of safety scale	**N** (schools)	**%**			
1 (least safe)	36	20.0	31.8	1.00 (referent)	
2	37	20.6	33.9	1.04 (0.92-1.18)	
3	36	20.0	37.2	1.16 (1.03-1.30)	
4	35	19.4	41.7	1.30 (1.16-1.44)	
5 (most safe)	36	20.0	40.9	1.30 (1.16-1.45)	<0.001
Availability of recreational facilities scale	**N** (schools)	**%**			
1 (fewest)	37	20.2	38.9	1.00 (referent)	
2	36	19.7	38.2	0.98 (0.86-1.10)	
3	37	20.2	36.8	0.91 (0.80-1.03)	
4	37	20.2	35.2	0.91 (0.79-1.02)	
5 (most)	36	19.7	35.2	0.88 (0.77-1.00)	0.019

Table 3. Multivariate analysis: associations between safety and recreational facilities and physical activity outside of school, by gender, grade, and geographic location

	GENDER[a]			GRADE[b]				LOCATION[c]			
	Male (n=4322)	Female (n=4791)		Elementary (n=1661)	Junior (n=3547)	High School (n=3906)		Urban metropolitan (n=5627)	Urban non-metropolitan (n=1854)	Rural (n=1568)	
	RR (95% CI)	RR (95% CI)	P*	RR (95% CI)	RR (95% CI)	RR (95% CI)	P*	RR (95% CI)	RR (95% CI)	RR (95% CI)	P*
Individual perceptions of safety											
1 (least safe)	1.00 (referent)	1.00 (referent)	0.006	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.007	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.042
2	1.11 (1.00-1.23)	1.18 (1.04-1.33)		1.15 (0.93-1.41)	1.03 (0.90-1.17)	1.23 (1.09-1.38)		1.12 (1.01-1.24)	1.23 (1.03-1.45)	1.12 (0.92-1.35)	
3 (most safe)	1.30 (1.16-1.44)	1.43 (1.24-1.63)		1.40 (1.12-1.71)	1.26 (1.09-1.44)	1.45 (1.26-1.64)		1.33 (1.17-1.48)	1.56 (1.29-1.84)	1.29 (1.04-1.56)	
P trend	*<0.001*	*<0.001*		*0.002*	*0.002*	*<0.0001*		*<0.001*	*<0.001*	*0.016*	
Group perceptions of safety											
1 (least safe)	1.00 (referent)	1.00 (referent)	<0.001	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.001	1.00 (referent)	1.00 (referent)	1.00 (referent)	<0.001
2	1.12 (0.96-1.28)	0.98 (0.81-1.16)		1.20 (0.86-1.60)	1.10 (0.90-1.33)	0.99 (0.84-1.18)		1.12 (0.95-1.30)	0.92 (0.66-1.23)	0.84 (0.52-1.25)	
3	1.08 (0.93-1.24)	1.13 (0.95-1.33)		1.36 (1.00-1.78)	1.03 (0.83-1.25)	1.10 (0.92-1.29)		1.19 (1.02-1.38)	0.81 (0.59-1.08)	1.04 (0.69-1.44)	
4	1.24 (1.07-1.41)	1.22 (1.02-1.43)		1.42 (1.05-1.84)	1.29 (1.04-1.56)	1.16 (0.97-1.35)		1.33 (1.13-1.54)	1.19 (0.84-1.56)	1.07 (0.72-1.46)	
5 (most safe)	1.23 (1.06-1.40)	1.16 (0.97-1.38)		1.55 (1.17-1.97)	1.19 (0.95-1.45)	1.09 (0.89-1.31)		1.43 (1.20-1.68)	0.94 (0.70-1.20)	1.02 (0.68-1.40)	
P trend	*0.004*	*0.008*		*0.005*	*0.072*	*0.103*		*<0.0001*	*0.851*	*0.337*	
Availability of recreational facilities											
1 (lowest)	1.00 (referent)	1.00 (referent)	<0.001	1.00 (referent)	1.00 (referent)	1.00 (referent)	<0.001	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.015
2	1.11 (0.96-1.27)	0.92 (0.77-1.08)		1.15 (0.88-1.43)	1.02 (0.83-1.22)	0.97 (0.79-1.16)		0.89 (0.68-1.13)	1.18 (0.91-1.46)	0.97 (0.78-1.16)	
3	1.08 (0.93-1.23)	0.87 (0.73-1.03)		0.85 (0.61-1.15)	0.92 (0.73-1.12)	1.04 (0.87-1.22)		0.87 (0.70-1.07)	1.07 (0.79-1.38)	0.97 (0.79-1.17)	
4	1.10 (0.93-1.27)	0.87 (0.71-1.05)		1.07 (0.79-1.38)	0.90 (0.71-1.11)	0.99 (0.80-1.20)		0.88 (0.71-1.07)	1.46 (0.95-1.94)	1.23 (0.83-1.64)	
5 (highest)	1.17 (0.99-1.34)	0.85 (0.69-1.02)		1.15 (0.81-1.51)	0.86 (0.66-1.07)	1.08 (0.88-1.29)		0.93 (0.75-1.12)			
P trend	*0.157*	*0.131*		*0.370*	*0.064*	*0.208*		*0.778*	*0.694*	*0.857*	

RR (95% CI)= rate ratio (95% confidence interval)

*P value for test of interactions

[a] RR were adjusted for grade, family affluence, urban location, perceptions of safety variables, availability of facilities

[b] RR were adjusted for gender, family affluence, urban location, perceptions of safety variables, availability of facilities

[c] RR were adjusted for grade, gender, family affluence, perceptions of safety variables, availability of facilities

Table 4. Effects of individuals' perceptions of safety on the relationship between availability of recreational features and physical activity outside of school

	INDIVIDUAL PERCEPTIONS OF SAFETY			
	Least safe (n=1859)	Safe (n=5073)	Most safe (n=1778)	
	RR (95% CI)	RR (95% CI)	RR (95% CI)	p*
Availability of recreational facilities				
1 (lowest)	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.001
2	0.97 (0.73-1.24)	0.96 (0.81-1.13)	1.16 (0.94-1.37)	
3	0.93 (0.73-1.17)	0.97 (0.82-1.14)	0.99 (0.78-1.20)	
4	0.82 (0.61-1.08)	1.02 (0.85-1.20)	0.99 (0.76-1.23)	
5 (highest)	0.81 (0.60-1.06)	1.05 (0.87-1.24)	1.07 (0.83-1.32)	
P trend	*0.069*	*0.508*	*0.810*	

RR (95% CI)= rate ratio (95% confidence interval)
RR were adjusted for gender, grade, family affluence, geographic location and group perceptions of safety
*p value for test of interactions

Chapter 5
General Discussion

5.1 Summary of Key Findings

The purpose of this thesis was to investigate associations between characteristics of school and neighbourhood environments and physical activity participation among Canadian youth in grades 6 through 10. In the first manuscript I observed that aspects of the school recreational environment are modestly positively related to adolescents' physical activity at school, particularly activity that occurs during free-time. The cumulative effect of school recreational features exerted a stronger effect than any single feature. These findings suggest that provision of recreational opportunities at school may promote physical activity among students.

Results from the second manuscript revealed that individual and peer perceptions of neighbourhood safety were modestly associated with adolescents' physical activity outside of school. Individuals' perceptions of safety were important for boys and girls of all ages in both rural and urban areas. Peer perceptions were important for younger youth (those in grade 6), perhaps reflective of an increased tendency of younger youth to be socially and spontaneously active outdoors. Increased availability of parks and recreational facilities neither prevented nor promoted physical activity.

5.2 Limitations of the Thesis

Both manuscripts were subject to some common limitations. First, both used a cross-sectional study design that did not permit a full exploration of temporality. It is plausible that schools might provide more opportunities to accommodate the interests of a

more active student population rather than the provision of opportunities influencing student activity. In the second analysis, it was possible that students' physical activity outdoors could influence their perceptions, rather than perceptions influencing behaviour.

Second, the analyses were limited to some degree by methodological challenges. Significant interactions were detected in each manuscript and therefore associations were explored within subgroups. Subsamples were smaller than the overall sample size; as such, subgroup analyses may have been underpowered. It was also not possible to consider multiple significant interactions simultaneously. In addition, no statistical adjustments were made for multiple comparisons; as such it is possible that some statistically significant associations may have occurred simply due to chance.

The second analyses presented in manuscript 2 were subject to additional limitations. First, only availability of parks and facilities was investigated; other aspects such as accessibility and quality of these facilities may be important factors to consider. Second, it would have been ideal to measure residential neighbourhoods using buffers constructed around individuals' homes; this was not possible since the *HBSC* is restricted from collecting information on student home addresses for reasons of confidentiality. It is possible that through use of a 5 km buffer around schools, neighbourhood characteristics may have been ascribed to students who in fact do not live within these radii. Finally, no standard method exists for assessment of neighbourhood environments. Thus, it was unclear which type of buffer should be used (radial versus street network buffers) and what radial distance around schools would be appropriate in capturing the residential neighbourhood of schools.

5.3 Strengths of the Thesis

Manuscript 1 is the first study to explore the individual and combined importance of physical education policies, recreational opportunities (e.g. sports programming), and facilities on physical activity participation at school within a large national sample. No studies to date have examined the effects of school recreational sports and policies on student engagement in physical activity. The second study (manuscript 2) is the first to examine the relative importance of perceptions of safety and availability of facilities on participation in physical activity among both boys and girls.

The thesis is also unique in its consideration of the broad Canadian context. To date, the effects of school characteristics have only been explored in rural Alberta. Although many studies of the effects of neighbourhood characteristics have been conducted in the United States and around the world, no Canadian studies of this topic exist.

The use of multilevel modeling in the statistical analyses was an additional methodological strength of this study, as it has a number of advantages. This modelling approach does not assume that observations are independent. Given that the *HBSC* survey uses a clustered sampling frame to select participants and that students within schools are likely to be more similar than students between schools, intraclass correlation is expected[1]. It would therefore be erroneous to assume independence. Second, multilevel analyses do not require that individual-level data be aggregated to the school-level or that school-level data be disaggregated to the individual[1]. Statistical issues arise with both of these methods: aggregating data to the school-level results in loss of statistical power by

using fewer units of observation, whereas disaggregating treats higher-level information as though it involved independent observations for each student, leading to overestimates of significance[1]. Multilevel modelling is more conservative than traditional regression but more liberal than an ecological approach. Third, hierarchical analyses allow cross-level interactions to be explored[1].

Finally, this analysis takes advantage of a large nationally representative sample of Canadian youth. It is generally assumed to be largely generalizable to Canada. Since adolescent physical activity rates, educational systems, and potentially neighbourhood environments may be similar across the United States and Europe, the findings of these studies may be largely generalizable to other industrialized countries.

5.4 Statistical Power

Due to the number of subgroup analyses explored in these manuscripts, power calculations were not performed for each subsample of students under study. Instead, the power of each sample in detecting a rate ratio of 1.2 was estimated. There is no standard method for calculating power in a multi-level analysis, hence power was estimated based on a classical power calculation adjusted for the design effect associated with the HBSC physical activity questions. The design effect estimates how the clustered nature of the survey data affects the standard errors of parameter estimates[2]. Snijders[2] states that "the required sample size for a multilevel design will be given by the sample size that would be required for a simple random sample design, multiplied by the design effect." Power calculations for first manuscript (Chapter 3) use an effective sample size of 5445, obtained by dividing the total sample size (n=7638) by the design effect for the HBSC

physical activity measures (deff=1.40)[3]. Power calculations for the second manuscript (Chapter 4) use an effective sample size of 6510 under the same assumption about clustering.

Given that class-time and free-time physical activity have a prevalence of 55% and 49%, respectively, the analyses in the first manuscript had between 85%-100% power to detect rate ratios of 1.2 at a 0.05 level of significance (Appendix Table E). The smallest effects detectable using the entire sample ranged from 1.07 to 1.18. Based on the prevalence of physical activity outside of school (36%), the analyses in the second manuscript had 100% power to detect rate ratios of 1.2 at a 0.05 level of significance. The smallest detectable effect based on the entire sample size was 1.10 (Appendix Table E).

5.5 Future Research Directions

Few existing studies have investigated the effects of the school environments on students' physical activity. Further research is warranted. Temporality of the relationships between the school environment and physical activity should be explored. Research that examines how school environments influence younger children's physical activity is lacking. In addition, future studies should investigate characteristics of physical education classes that promote class-time physical activity.

Study of neighbourhood characteristics as determinants of physical activity is a newly emerging field. As such, there is a lack of consistency in how neighbourhoods are measured. Measurement of physical activity varies considerably and it is unclear what levels of physical activity are optimal. Development of a standard approach to

measurement of the built environment and physical activity in youth would improve comparability between studies.

Future studies should consider the effects of different aspects of neighbourhood safety on youth physical activity, in particular the importance of perceptions of social and physical dangers. It is important to understand the extent to which perceptions match the objective environment in order to inform population-based interventions. Consideration of the accessibility, affordability, and quality of public recreational spaces is also required.

5.6 Public Health and Policy Implications

Although the effects of school environments and perceptions of safety on physical activity were modest, school and neighbourhood environment are ubiquitous; taken together with their high prevalence, these exposures may be important in influencing physical activity behaviours. Changes to the school and neighbourhood environment, in terms of better and increased school recreational opportunities and increased neighbourhood safety, could improve physical activity rates among adolescents. Not only would increased physical activity participation translate into immediate health benefits for youth, but it may also reduce the future incidence of physical inactivity-related chronic diseases.

The results of manuscript 1 revealed that high levels of recreational support at schools might promote physical activity among young people. This could not only inform educational policies for intramural sports and extracurricular activity, but also

support funding of these opportunities. In addition, this research could support funding improvements to school gymnasia and sport fields.

Interventions aimed at improving the safety of neighbourhoods, along with those aimed at increasing individuals' perceptions of safety, could potentially be effective in promoting outdoor physical activity among children and adolescents. Such interventions might involve promoting social interaction among community members or more tangible improvements to neighbourhoods, such as an increased police presence, safer facilities, traffic calming measures, and physical improvements to roads.

5.7 References

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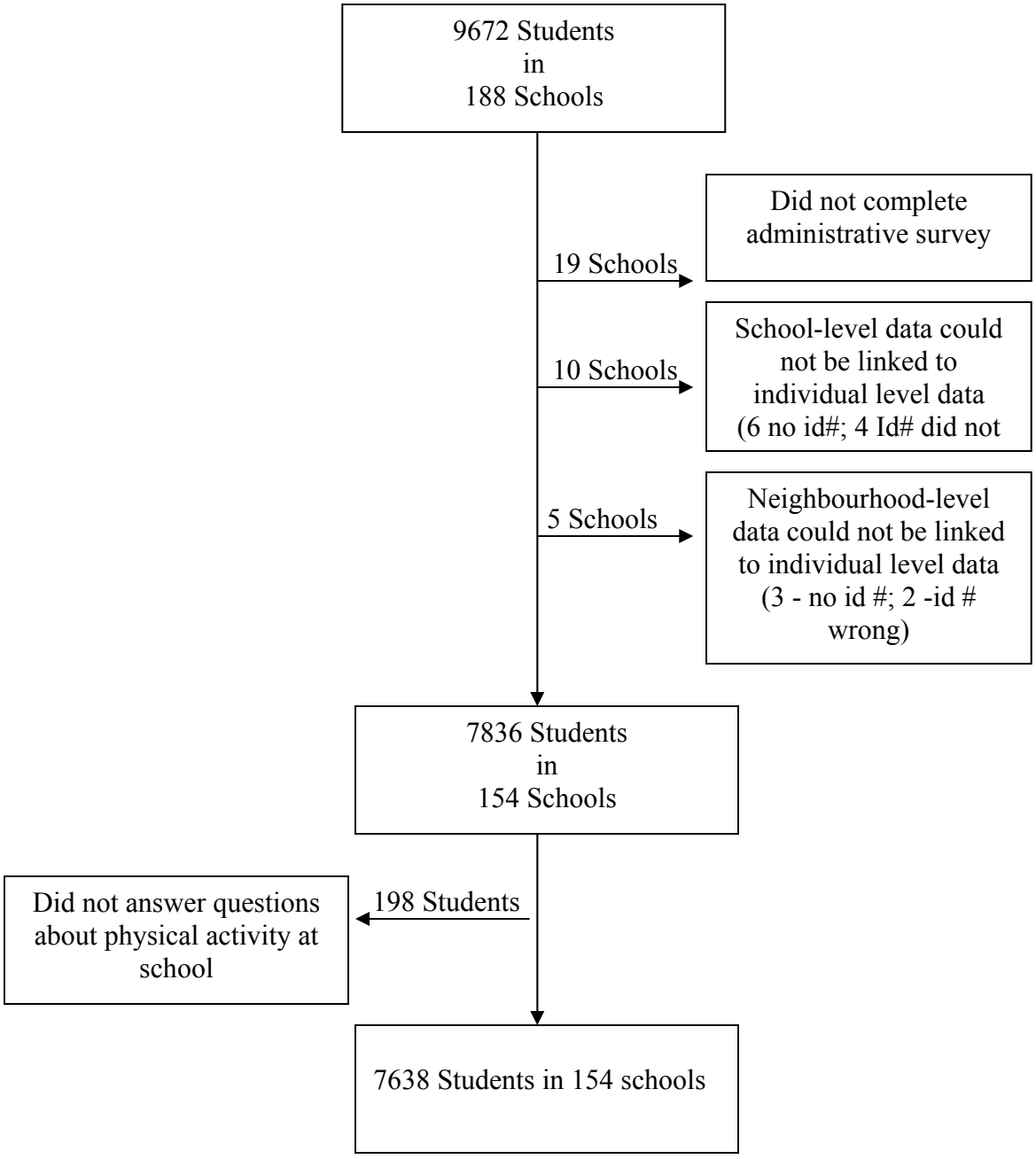
Appendix A

Exclusion Flow Chart for Manuscript 1



Appendix B

Additional Analyses for Manuscript 1

Table A. Spearman rank correlation between school-level variables

	Policy	PE	Varsity Sports	Intramural Sports	Late Bus	Field	Condition of Field	Gym	Condition of Gym
Policy	-								
PE	0.14	-							
Varsity sports	-0.08	-0.17*	-						
Intramural sports	-0.02	0.006	0.09	-					
Late Bus	0.14	0.05	0.03	-0.11	-				
Playing Field	0.04	-0.05	0.01	0.04	-0.11	-			
Condition of Field	-0.11	0.02	0.02	-0.19*	0.10	N/A	-		
Gym	-0.03	-0.04	0.16	-0.03	0.08	-0.08	0.08	-	
Condition of gym	0.03	-0.04	-0.06	-0.04	0.14	-0.07	0.23**	N/A	-

*p<0.05 **p<0.01 ***p<0.001 ****p<0.0001

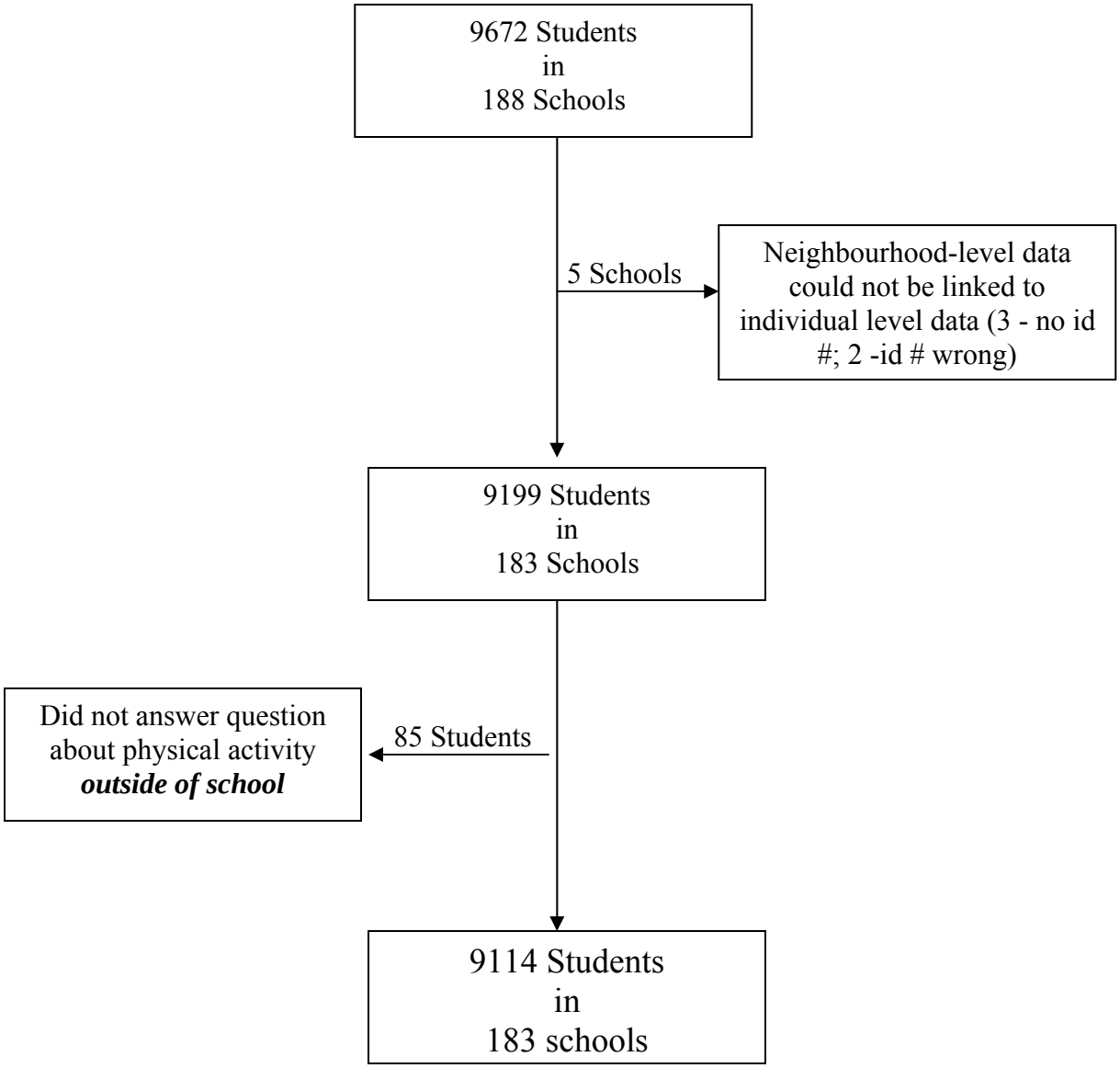
Table B. Chi-square values of relationships between school-level variables

	Policy	PE	Varsity Sports	Intramural Sports	Late Bus	Field	Condition of Field	Gym	Condition of Gym
Policy	-								
PE	2.84	-							
Varsity sports	1.72	4.87	-						
Intramural sports	0.96	3.51	2.52	-					
Late Bus	3.16	0.35	0.14	2.13	-				
Playing Field	0.21	0.35	0.31	0.40	1.72	-			
Condition of Field	2.29	0.59	0.86	7.79	1.60	4.83	-		
Gym	0.14	0.29	6.50*	0.20	0.92	0.91	0.97	-	
Condition of gym	0.18	1.25	2.72	3.96	3.42	0.82	11.77*	1.45	-

*p<0.05 **p<0.01 ***p<0.001 ****p<0.0001

Appendix C

Exclusion Flow Chart for Manuscript 2



Appendix D

Additional Analyses for Manuscript 2

Table A. Principle component factor analysis results for variables comprising the school safety variable.

Variable	Factor loading	Eigenvalue	Cronbach's alpha
Feel safe in local area	0.84545	0.7148	0.6819
Area is good place to live	0.85299	0.7276	
Safe to play outside	0.65921	0.4345	

Table B. Spearman rank correlation coefficients for scales of neighborhood facilities, perceived and actual neighborhood safety

	Individual perceptions of safety	Group perceptions of safety	Facilities
Individual perceptions of safety	1.00		
Group perceptions of safety	0.28****	1.00	
Facilities	-0.08****	-0.24****	1.00

****p<0.0001

Table C. Spearman correlation matrix of number of parks and facilities within 5 km

	Parks	Trails	Arenas	Community Centres	Sportsplexes/ Stadiums	Pools
Parks	1.00					
Trails	0.54****	1.00				
Arenas	0.56****	0.45****	1.00			
Community Centres	0.46****	0.35****	0.31****	1.00		
Sportsplexes/ Stadiums	0.51***	0.43****	0.47****	0.51****	1.00	
Pools	0.44****	0.37****	0.43****	0.51****	0.49****	1.00

*p<0.05
**p<0.01
***p<0.001
****p<0.0001

Table D. Distribution and bivariate associations between potential confounders and students' physical activity outside of school

Variable			Physically active at least 4 hours/week outside of school %	Unadjusted RR (95% CI)
Individual-level	**N** (individuals)	**%**		
Perceived litter in neighbourhood				
Lots	629	7.1	36.1	1.00 (referent)
Some	3536	39.9	37.8	1.05 (0.94-1.17)
None	4706	53.0	35.6	1.01 (0.91-1.13)
Perceived run-down houses				
Lots	228	2.6	38.2	1.00 (referent)
Some	1736	19.6	38.1	1.00 (0.84-1.19)
None	6897	77.8	36.7	0.96 (0.81-1.14)
Neighborhood -level	**N** (schools)	**%**		
Urban/rural location (4 groups)				
Urban inside CMA	111	61.0	35.7	1.00 (referent)
Urban outside CMA	42	23.1	37.2	1.06 (0.96-1.17)
Rural	29	15.9	40.4	1.13 (1.01-1.24)
Neighbourhood socioeconomic status				
Quintile 1 (lowest)	37	20.1	38.1	1.00 (referent)
Quintile 2	37	20.1	33.8	0.86 (0.75-0.98)
Quintile 3	37	20.1	37.6	0.97 (0.86-1.09)
Quintile 4	36	19.6	33.5	0.89 (0.78-1.01)
Quintile 5 (highest)	37	20.1	40.4	1.04 (0.92-1.16)

*CMA= Census metropolitan area

Table E. Distribution individual recreational features and their bivariate association with adolescent physical activity.

Facilities within 5 km	Distribution of Sample		Physically active at least 4 hours/week		
	N	**%**	**%**	**Unadjusted RR (95% CI)**	P trend
Individual recreational facilities					
Parks					
None	15	8.2	39.6	1.00 (referent)	
1-3	56	30.6	37.6	0.95 (0.81-1.09)	
4-19	52	28.4	37.7	0.95 (0.81-1.10)	
20+	60	32.8	34.8	0.87 (0.74-1.01)	0.0465
Trails					
None	73	39.9	37.9	1.00 (referent)	
1-3	48	26.2	37.6	0.99 (0.90-1.09)	
4-19	52	28.4	34.7	0.90 (0.81-0.99)	
20+	10	5.5	36.3	0.95 (0.77-1.14)	0.0629
Arenas					
None	54	29.5	37.1	1.00 (referent)	
1	66	36.1	37.8	1.01 (0.92-1.11)	
2-4	46	25.1	37.9	1.00 (0.90-1.11)	
5+	17	9.3	30.0	0.80 (0.68-0.94)	0.0504
Community Centres					
None	130	71.0	37.3	1.00 (referent)	
1	30	16.4	36.6	1.00 (0.89-1.11)	
2-4	20	10.9	35.9	0.94 (0.82-1.07)	
5+	3	1.6	25.8	0.64 (0.43-0.93)	0.0742
Sportsplexes/Stadium					
None	135	73.8	37.7	1.00 (referent)	
1	28	15.3	34.4	0.87 (0.77-0.98)	
2-4	20	10.9	35.2	0.93 (0.81-1.05)	0.0580
5+	0	0	-	-	
Pools					
None	151	82.5	37.1	1.00 (referent)	
1	11	6.0	37.4	1.03 (0.87-1.20)	
2-4	16	8.7	37.8	0.99 (0.85-1.14)	
5+	5	2.7	29.0	0.77 (0.59-0.99)	0.1828

Table F. Associations between neighbourhood recreational features and adolescent physical activity by gender and grade

	GENDER [a]			GRADE [b]			
	Male (n=4322) RR (95% CI)	Female (n=4791) RR (95% CI)	p*	Elementary (n=1661) RR (95% CI)	Junior (n=3547) RR (95% CI)	High School (n=3906) RR (95% CI)	p*
***Facilities*‡**							
Arenas							
None	1.00 (referent)	1.00 (referent)	0.0001	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0001
1	1.02 (0.91-1.13)	0.98 (0.86-1.10)		1.13 (0.90-1.38)	0.95 (0.82-1.09)	0.98 (0.85-1.11)	
2-4	1.13 (0.99-1.27)	0.93 (0.79-1.09)		1.14 (0.87-1.43)	0.85 (0.70-1.02)	1.16 (0.98-1.33)	
5+	1.00 (0.83-1.18)	0.77 (0.60-0.96)		1.11 (0.78-1.49)	0.70 (0.54-0.88)	1.08 (0.85-1.33)	
Community Centres							
None	1.00 (referent)	1.00 (referent)	0.0001	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0002
1	1.12 (0.99-1.24)	1.14 (0.99-1.30)		1.07 (0.87-1.28)	1.02 (0.86-1.19)	1.00 (0.85-1.16)	
2-4	1.08 (0.94-1.23)	1.10 (0.93-1.29)		1.30 (1.00-1.62)	0.96 (0.76-1.15)	1.04 (0.87-1.21)	
5+	0.83 (0.55-1.16)	0.80 (0.51-1.19)		0.51 (0.23-0.98)	0.65 (0.35-1.09)	1.17 (0.73-1.64)	
Sportsplexes/Stadiums							
None	1.00 (referent)	1.00 (referent)	0.0036	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0244
1	0.94 (0.82-1.06)	0.92 (0.79-1.06)		0.94 (0.74-1.17)	0.81 (0.67-0.97)	1.01 (0.85-1.18)	
2+	1.06 (0.91-1.20)	0.92 (0.76-1.09)		0.98 (0.71-1.28)	0.93 (0.76-1.12)	1.07 (0.90-1.25)	
Pools							
None	1.00 (referent)	1.00 (referent)	0.0001	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0002
1	1.02 (0.85-1.20)	1.12 (0.92-1.35)		1.41 (1.09-1.74)	0.92 (0.68-1.21)	1.01 (0.80-1.24)	
2-4	1.23 (1.08-1.38)	0.80 (0.64-0.99)		1.12 (0.83-1.45)	1.02 (0.81-1.26)	1.04 (0.86-1.24)	
5+	0.76 (0.56-0.99)	0.98 (0.73-1.27)		0.88 (0.48-1.41	0.69 (0.47-0.96)	1.10 (0.81-1.42)	

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Parks & Trails‡							
Parks							
None	1.00 (referent)	1.00 (referent)	0.0002	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0028
1-3	1.15 (0.95-1.34)	0.86 (0.69-1.04)		1.09 (0.74-1.49)	0.91 (0.70-1.14)	1.08 (0.76-1.43)	
4-20	1.17 (0.94-1.39)	0.93 (0.73-1.15)		1.21 (0.78-1.70)	0.91 (0.66-1.18)	1.19 (0.80-1.59)	
20+	1.13 (0.90-1.37)	0.87 (0.67-1.10)		1.15 (0.72-1.65)	0.84 (0.60-1.11)	1.13 (0.74-1.56)	
Trails							
None	1.00 (referent)	1.00 (referent)	0.0003	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0009
1-3	1.09 (0.98-1.20)	0.95 (0.83-1.08)		0.97 (0.79-1.17)	0.97 (0.83-1.13)	1.13 (0.99-1.28)	
4-20	1.05 (0.93-1.18)	0.88 (0.75-1.02)		0.76 (0.58-0.96)	0.94 (0.78-1.11)	1.12 (0.96-1.28)	
20+	1.02 (0.81-1.25)	1.00 (0.78-1.24)		0.86 (0.56-1.22)	0.96 (0.59-1.40)	1.12 (0.89-1.36)	

RR (95% CI)= Rate ratio (95% confidence interval)

[a] RR were adjusted grade, family affluence, perceived neighbourhood safety, geographic location

[b] RR were adjusted gender, family affluence, perceived neighbourhood safety, geographic location

*p value for test of significant for interactions

Table G. Associations between neighbourhood recreational features and adolescent physical activity by perceived neighbourhood safety and geographic location

	PERCEIVED SAFETY [a]				LOCATION [b]		
	Least safe (n=1859) RR (95% C.I)	Safe (n=5073) RR (95% C.I)	Most safe (n=1778) RR (95% C.I)	p*	Urban inside CMA (n=5627) RR (95% C.I)	Urban outside CMA (n=1854) RR (95% C.I)	Rural (n=1568) RR (95% C.I)
***Facilities*‡**							
Arenas							
None	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0016	1.00 (referent)	1.00 (referent)	1.00 (referent)
1	1.03 (0.85-1.22)	0.99 (0.88-1.11)	1.00 (0.85-1.16)		1.11 (0.95-1.28)	0.90 (0.73-1.07)	0.95 (0.81-1.08)
2-4	0.89 (0.69-1.12)	1.09 (0.94-1.24)	1.05 (0.85-1.26)		1.10 (0.94-1.27)	1.05 (0.73-1.41)	n/a
5+	**0.72 (0.53-0.96)**	1.03 (0.84-1.23)	**0.76 (0.53-0.96)**		0.96 (0.79-1.16)	n/a	n/a
Community Centres							
None	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0180	1.00 (referent)	1.00 (referent)	1.00 (referent)
1	0.99 (0.87-1.13)	1.04 (0.91-1.18)	1.03 (0.86-1.21)		1.07 (0.93-1.21)	1.07 (0.94-1.21)	1.05 (0.71-1.42)
2-4	1.10 (0.94-1.27)	1.09 (0.93-1.26)	1.05 (0.84-1.27)		1.05 (0.92-1.19)	1.08 (0.88-1.34)	n/a
5+	1.03 (0.83-1.26)	0.94 (0.61-1.33)	0.70 (0.34-1.20)		0.75 (0.51-1.06)	0.66 (0.40-1.10)	n/a
Sportsplexes/Stadiums							
None	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0575	1.00 (referent)	1.00 (referent)	1.00 (referent)
1	0.92 (0.75-1.12)	0.89 (0.76-1.02)	1.00 (0.82-1.18)		0.89 (0.78-1.02)	0.95 (0.54-1.47)	1.06 (0.86-1.26)
2+	0.86 (0.66-1.10)	1.04 (0.88-1.20)	1.03 (0.82-1.24)		1.00 (0.87-1.13)	n/a	n/a
Pools							
None	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0024	1.00 (referent)	1.00 (referent)	1.00 (referent)
1	1.16 (0.89-1.45)	0.96 (0.78-1.17)	1.21 (0.94-1.47)		1.07 (0.89-1.26)	1.09 (0.65-1.60)	n/a
2-4	0.86 (0.64-1.11)	1.10 (0.93-1.28)	1.12 (0.89-1.36)		1.05 (0.90-1.21)	n/a	n/a
5+	**0.62 (0.38-0.97)**	0.88 (0.65-1.15)	1.04 (0.69-1.40)		0.86 (0.66-1.09)	n/a	n/a

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Parks & Trails‡							
Parks							
None	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0001	1.00 (referent)	1.00 (referent)	1.00 (referent)
1-3	0.86 (0.60-1.17)	0.93 (0.76-1.12)	1.27 (0.97-1.56)		1.26 (0.81-1.76)	0.94 (0.42-1.64)	0.98 (0.86-1.12)
4-20	1.01 (0.70-1.39)	0.97 (0.77-1.19)	1.27 (0.92-1.61)		1.18 (0.76-1.66)	1.07 (0.49-1.78)	1.30 (0.90-1.70)
20+	0.82 (0.54-1.17)	1.01 (0.80-1.23)	1.15 (0.81-1.52)		1.16 (0.75-1.64)	n/a	n/a
Trails							
None	1.00 (referent)	1.00 (referent)	1.00 (referent)	0.0323	1.00 (referent)	1.00 (referent)	1.00 (referent)
1-3	1.04 (0.86-1.25)	1.03 (0.91-1.15)	1.00 (0.85-1.16)		0.97 (0.83-1.12)	1.14 (0.96-1.34)	0.96 (0.82-1.12)
4-20	0.90 (0.72-1.11)	0.98 (0.85-1.12)	0.97 (0.79-1.15)		0.91 (0.79-1.04)	1.33 (0.96-1.72)	0.69 (0.27-1.36)
20+	0.87 (0.60-1.20)	1.10 (0.88-1.34)	0.94 (0.63-1.27)		0.97 (0.76-1.20)	n/a	1.04 (0.81-1.28)

RR (95%CI)= Rate ratio (95% confidence interval)

[a] RR were adjusted gender, grade, family affluence, geographic location

[b] RR were adjusted gender, grade, family affluence, perceived neighbourhood safety

*p value for test of significant for interactions

Appendix E

Power Calculations

		Class-time physical activity (prevalence=55%)		Free-time physical activity (prevalence=49%)	
	Prevalence of outcome %	Smallest detectable RR with 80% power	Power to detect RR=1.20	Smallest detectable RR with 80% Power	Power to detect RR=1.20
Manuscript 1					
Has a policy	64.7	1.076	100%	1.086	100%
Playing field	92.2	1.146	96%	1.167	91%
Gymnasium	93.5	1.162	92%	1.185	85%
Good Field Condition	66.2	1.075	100%	1.084	86%
Good Gym Condition	83.4	1.151	95%	1.172	88%
4+ Intramural sports	45.8	1.094	100%	1.107	97%
4+ Varsity sports	24.0	1.072	100%	1.081	86%
5-6 recreational features	28.9	1.137	97%	1.156	88%
		Physical activity outside of school (prevalence=36%)			
Manuscript 2					
Individual perceptions of safety	20.4	1.096	100%		
Group perceptions of safety	20.0	1.096	100%		
Availability of Facility Scale	19.7	1.093	100%		

Level of significance = 0.05; Power= 80%
P is the proportion of students who have the outcome (i.e. are physically active)

Power $= \Phi Z_{(1-\beta)}$
$= \Phi \{d [(nr)/P(1-P)(1+r)]^{1/2} - Z_{\alpha/2}\}$
r is the ratio of unexposed to exposed
p_o is the prevalence of physical activity in the *unexposed*
p_1 is the prevalence of physical activity in the *exposed*
d is the difference between p_1 and p_o
$z_{\alpha/2}$ is the level of significance

Appendix F
HBSC Survey Methodology

The research within the thesis involved analysis of data from the 2005/06 Canadian *HBSC*. A total of 9672 students participated from 188 schools across all provinces and territories. The survey is self-weighting and used a single-stage cluster sampling design, with randomly selected classrooms reflecting the provincial distributions of schools by size, location, language, and religion. Using school directories and lists, the number of classes in schools was estimated based on the number of teachers, the total student enrolment, enrolment by grade, and number of grades in the school. Classes were systematically selected from an ordered list based on school jurisdiction, province, language, public/Roman Catholic designation, community size, and community location, giving classes an approximately equal probability of being selected. Youth attending private, special-needs, or home schools were excluded, as were institutionalized, incarcerated, or homeless youth.

Ethics approval was obtained from Queen's University's General Research Ethics Board. Permission was solicited from school boards and individual schools. Consent was required from student participants and their parent or guardian. Approximately 74% of students in the sample participated, of which less than 10% declined participation or spoiled the questionnaire. Other non-participants were students who failed to return the parental consent form, who did not receive parental consent, or who were absent from school when the survey was administered.

Teachers administered the 40-minute pen and paper survey during class time, typically within the classroom setting. Having students seal un-signed surveys in

envelopes ensured anonymity. Student responses may have been influenced by, for example, communication between students during administration of the survey, student interpretation of the question, or lack of privacy while completing the survey.

Reference

Boyce WF, King MA, Roche J. Healthy settings for young people in Canada. Health Behaviour in School-Aged Children, Public Health Agency of Canada. 2007