

RISK-TAKING BEHAVIOUR AND SCHOOL INJURY IN CANADIAN ADOLESCENTS

by

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ABSTRACT

Background: Adolescent school injuries are common and often result in serious consequences. Problem risk behaviours are known causes of injury and interventions have targeted these independent behaviours with modest success in the past. Although there is some research investigating relationships between risk behaviours, none have empirically evaluated measures of multiple risk behaviour using a theoretical framework of adolescent risk-taking. There is a need for research to utilize population health theory to investigate associations between measures of multiple risk behaviour and school injury.

Objectives: The objectives of this thesis are to: 1) investigate the relationships between risk behaviours among a sample of Canadian adolescents using a framework of adolescent risk-taking, and 2) to evaluate adolescent risk behaviours and school climate as independent, and perhaps interactive, determinants of school injury under the Population Health Framework.

Methods: Both objectives utilized an interim dataset from the 2014 Health Behaviour in School-aged Children (HBSC) Study. *Objective 1.* Factor-analytically derived (and validated) scales of multiple risk behaviours were used to describe relationships between these behaviours. *Objective 2.* Students reported their experiences with different types of school injury. Relationships between multiple risk behaviour and school injuries were assessed. The influence of school climate on that relationship was also evaluated.

Results: *Objective 1.* Adolescent risk behaviours appear to cluster into three distinct categories: 1) Overt Risk-Taking, 2) Active Healthy Lifestyle Detriment, and 3) Passive Healthy Lifestyle Detriment.

Objective 2. Young, overt-risk takers were identified as a specific high-risk group for general school injuries, as well as several sub-types of school injury. School climate influences relationships between risk behaviour and school injury in complex and context-specific ways. The inconsistency of its effects suggests that it is not an effect modifier.

Conclusions: *Objective 1.* Currently, surveillance, intervention programs, and research target isolated domains of risk behaviour. This thesis shows that risk behaviours cluster in predictable ways and should be studied and addressed in their related groups. *Objective 2.* Associations between multiple risk behaviour and school injury appear to be strongest among younger students. Effects of school climate on these relationships cannot be easily generalized across different grades or injury types.

CO-AUTHORSHIP

This thesis presents the work of Jonathan Kwong in collaboration with his advisors, Dr. William Pickett and Dr. Don Klinger.

Manuscript 1. *Adolescent Risk Taking in Canada: A contemporary empirical study of the CDC framework.* The idea to study adolescent risk behaviour was Dr. Pickett's. Jonathan Kwong developed the concept of evaluating risk behaviour using the CDC risk behaviour framework. Dr. Pickett and Jonathan Kwong outlined the objectives of this study. Jonathan Kwong and Dr. Pickett conceived the analysis plan, with expertise from Dr. Klinger on psychometric methods. Jonathan Kwong wrote the manuscript, conducted the statistical analyses, and interpreted the results with guidance and editorial feedback from Dr. Pickett and Dr. Klinger.

Manuscript 2. *Assessment of contemporary risk behaviour scales and school climate as interactive determinants of school injury in Canadian adolescents.* The concept of studying school injury in the context of a population health framework was Dr. Pickett's. Jonathan Kwong and Dr. Pickett decided to study school climate and adolescent risk behaviour as the possible determinants of school injury. Jonathan Kwong wrote the manuscript, conducted the statistical analyses, and interpreted the results with guidance and editorial feedback from Dr. Pickett and Dr. Klinger.

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LIST OF ABBREVIATIONS

HBSC Health Behaviour in School-aged Children Study

CDC US Centers of Disease Control and Prevention

SES Socioeconomic Status

Chapter 1

Introduction

1.1 Overview

Adolescent school injuries are common and often result in serious and long-term consequences to both the child as well as their caregivers. In 2010, approximately 20% of all adolescent injuries occurred at school and one-third of those school injuries were serious enough to require significant medical attention.¹ Although school injuries have been studied extensively,²⁻⁴ and a variety of preventive interventions have been targeted towards different potential causes,⁵ rates of school injury have remained relatively unchanged from 2001 to 2010.^{1,6,7}

In this thesis, I propose two areas of improvement to the study of school injuries and their etiology: 1) the development of a better conceptualization and hence measurement of adolescent risk behaviours – known causes of school injury,^{8,9} and; 2) an adoption of a population health theory and an associated framework¹⁰ to evaluate simultaneous and possible synergistic causes of school injury.

1.1.1 Conceptualizing Adolescent Risk Behaviour

Conceptualizations of adolescent risk behaviour vary dramatically between fields of scientific enquiry, and even within epidemiological research. Traditionally, epidemiological studies of adolescent risk-taking have considered the independent effects of behaviours such as smoking, drinking and driving, and dietary patterns on a variety of health outcomes, including injury.¹¹ Based on this research, the US Centers of Disease Control and Prevention (CDC) created a framework describing the risk behaviours most closely associated with morbidity and mortality among American youths to be used for research, public health surveillance, and intervention planning.⁹ The six domains of the CDC framework are: smoking cigarettes, alcohol and illicit substance use, high-risk sexual behaviours, high-risk manifest behaviours, unhealthy dietary patterns, and physical inactivity. However, psychological theory (Problem Behaviour Theory¹²) suggests that such risk behaviours are linked or clustered, and may not develop or be

expressed in isolation as the CDC framework suggests. Incorrect conclusions about relationships that exist between risk behaviours could have important consequences on their observed associations with injury, as well as the basis and theory underlying public health interventions. This thesis investigates the relationships amongst risk behaviours by empirically testing the six-domain CDC framework, and then offering recommendations surrounding its refinement and application.

1.1.2 Population Health Framework

Research on school injuries has typically focused on individual (e.g., adolescent risk behaviour) or contextual causes (e.g., social supports at school). However, developments in population health theory suggest these individual and contextual causes may interact together and alter their independent relationships with school injury. The Public Health Agency of Canada's Population Health Framework¹⁰ proposes that individual and contextual determinants each have independent, and perhaps interactive effects on injury and illness. Although this framework has existed for some time, it has rarely been tested empirically in population-based studies.¹³ The Population Health Framework remains an important way of thinking that could have a significant impact on the way that mechanisms of school injury are understood and future interventions are planned. The Population Health Framework will be tested in this thesis by considering the individual and potentially interactive effects of adolescent risk behaviour (an individual-level determinant) and school social climate (a contextual determinant) on the occurrence of school injuries.

1.1.3 School Climate as a Contextual Determinant of School Injury

School climate has been described as the social atmosphere and sense of belonging and comfort that students perceive from their teachers and peers.¹⁴ Studies have observed reductions in risk behaviour participation as well as school injuries based on interventions aimed at improving school climate.¹⁵ Other studies have also observed potential mechanisms by which aspects of school climate are able to modify risk behaviours to prevent injuries at school.² Although these separate relationships have been tested in

isolation, a comprehensive study is needed to evaluate its real-world application. In addition to the work involving refinement of risk behaviour scales, my thesis empirically tests the Population Health Framework by evaluating the direct and potential interactive effects of school climate (with risk behaviour) on school injury risk.

1.2 Thesis Aim

This thesis aims to develop a better understanding of the etiology of school injuries by developing a better conceptual theory of risk-taking behaviour, a known cause of school injuries, and by utilizing the Population Health Framework to investigate dual-levels of the determinants of injury.

1.3 Societal Importance

Results from this thesis have important implications on our understanding of adolescent risk behaviour and school injuries. First, the current and widespread use of the CDC risk framework in surveillance, intervention and research indicates that it is a helpful conceptualization, yet its underlying theory should be assessed more thoroughly to confirm its utility, especially in non-US populations.¹⁶ Second, improvement of the CDC risk framework has the opportunity to affect the ways that injury prevention programs that aim to target risk behaviours are designed in the future. Programs targeting upstream factors related to multiple risk behaviours may be more effective at preventing their associated illness and injury outcomes.¹³ Third, this study addresses the need to consider multi-level theories of potential causes of injury. Our research recognizes the complex etiological nature of school injury and uses population health theory to support our theoretical framework. By considering a potential contextual determinant of injury, we may be able to identify an environmental point of intervention that is helpful to injury prevention efforts.

In summary, school injuries represent an important public health concern because of their high incidence and their serious consequences towards the successful development of the child.¹ This thesis addresses the following knowledge gaps that will contribute to improvements in future school injury

prevention efforts: 1) although individual domains of adolescent risk behaviour have been identified, use of Problem Behaviour Theory is required to understand the true breadth and depth of clusters of adolescent risk behaviour through an empirical analysis, and 2) the Population Health Framework has rarely been tested and represents a useful way to understand and subsequently plan interventions to prevent school injuries; school climate and adolescent risk behaviours represent determinants of injury from two levels (individual and contextual) that will be used to test this framework.

1.4 Objectives and Hypothesis

This thesis investigates the inter-relationships between adolescent risk behaviours, as well as school injuries within the context of the Population Health Framework. Adolescent risk behaviours and school climate are known determinants of school injury that will be used to test the Population Health Framework. This thesis is written in a manuscript-style format and is organized as follows:

1.4.1 Adolescent Risk Taking in Canada: A contemporary empirical study of the CDC framework

Although the CDC has categorized the risk behaviours associated with the leading causes of morbidity and mortality among American youths, the six risk behaviour domains within the framework are isolated and have never been subject to empirical testing.⁹ The CDC framework is currently used as the basis for much research, surveillance, and policy development.¹⁶ However, it is now known that a variety of risk behaviours develop concurrently among adolescents based on Problem Behaviour Theory.¹² The current manuscript uses the 2014 Health Behaviour in School-aged Children Study to assess the real-world utility of the six-domain CDC risk framework. Empirical analyses will be used to evaluate relationships between risk behaviours across all six domains from the CDC framework. It was hypothesized that CDC risk domains are inter-related and that clusters of risk behaviour would emerge with representation from several CDC domains.

1.4.2 Assessment of contemporary risk behaviour scales and school climate as interactive determinants of school injury among Canadian adolescents

School injuries represent a burden of disease that have serious health consequences to adolescents and are largely preventable.^{1,2} Relationships between individual risk behaviours and injury have been studied extensively in the past. However, there is a paucity of research that considers relationships between several distinct composite measures of risk and injury. This study used the three empirically derived categories of adolescent risk behaviour from Manuscript 1 to assess their individual relationships with school injury. Given the known contextual influence of school climate,¹⁵ it was assessed alongside adolescent risk behaviour as a potential effect modifier, as well as being a direct determinant of school injury. It was hypothesized that our conceptualizations of risk behaviour would be associated with school injury. We also hypothesized that positive school climate would have a protective role in mitigating the relationship between risk behaviour and school injury.

1.5 Thesis Organization

This thesis conforms to the Queen's University School of Graduate Studies and Research Guideline "General Forms of Thesis".¹⁷ The second chapter is a literature review of school injuries and its known determinants, specifically, adolescent risk behaviour, and school climate. An emphasis on Population Health Theory is also reviewed. The third chapter is Manuscript 1, which presents an empirical assessment of the relationships between adolescent risk behaviours. This manuscript is intended for publication in the journal *JAMA Pediatrics*. The fourth chapter is Manuscript 2, which utilizes Population Health Theory to evaluate risk behaviour and school climate as potential individual and interactive determinants of school injury. This manuscript has been developed for publication in the journal *Injury Prevention*. Chapter five connects both manuscripts through a general discussion and outlines potential policy implications and areas of future research.

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Chapter 2

Literature Review

2.1 School Injury

The school is an environment in which injuries to adolescents occur frequently. In Canada, approximately 20% of adolescents who sustained an injury within the last year reported that it happened at school (either during or after school hours).¹ About one-third of all school injuries were serious and required an absence from school or a student's usual activities for at least five days. As with injuries occurring in any other environment, unintentional school injuries can have significant physical and economic costs. Serious injuries to adolescents are especially detrimental because they result in a greater number of years of reduced quality of life, potential consequences to normative development, and high, long-term financial cost.² In 2004, unintended injuries to adolescents in Canada amounted to over \$730 million in direct and indirect costs.³ Preventable injuries also claim the lives of more Canadian children than any other cause.⁴ Hence school injuries in adolescents are common and have clear, serious, and long-term physical and economic consequences.

Although types of school injuries can be heterogeneous, the three most common activities that students participate in when they sustain injuries at school are: 'walking or running (non-sport)', 'playing or training for sport', and 'fighting'.⁵ These actions may occur during a number of school-related and free-time activities. School-related activities such as physical education classes or organized sporting events may result in injuries from walking/running or training for a sport. Free-time activities are those that occur during designated leisure times such as recess periods, lunch breaks, or unsupervised after-school activities on school grounds. In Canada, there are approximately four times more injuries reported to occur during extended lengths of free-time activities when compared to school-related activities.⁵ Therefore, unstructured free-time activities represent an important period of a student's day in which they are at heightened risk of injury at school and an area for potential injury prevention interventions.

Previous interventions have attempted to develop an understanding of the high-risk activities that students participate in during leisure time, and have also shown that injuries associated with these high-risk activities may be preventable. Among younger students in elementary school, observational research on playground activities showed that aggressive behaviours (i.e., wrestling, pulling, and hitting) and the misuse of playground equipment contributed to a large number of injuries during recess periods.⁶ Research on older students in a high-school setting typically focus on two main activities predominantly associated with school injuries (which may or may not occur during their periods of free-time) – training for sports and physical fighting.^{7,8} Through intervention programs aimed at targeting specific student groups or the entire school environment, reductions in various types of school injuries have been observed in both elementary and high schools.

A review of universal school-based injury prevention programs showed that interventions targeting behaviour modification, social skills development, and a change in school norms could reduce violence and bullying among elementary and high school students.⁹ Findings from these programs demonstrate two important messages – 1) many school injuries are preventable, and 2) social changes to the school environment have an impact on risks for injury. However, the range of programs and outcomes suggest that further research is needed to understand what aspects of injury etiology these programs could potentially influence in order to mitigate potential causes of injury.

2.2 School Environments and School Climate Scales

Schools represent a unique environment because of the influence they have on the social development of adolescents. The perception that students and teachers have of their school environment has been shown to have a significant relationship with a wide range of physical health, mental health, and academic outcomes.¹⁰ The way that students perceive their school's safety, inclusion, relationships, authoritative structure, norms, and pedagogical practices is broadly referred to as 'school climate' (also referred to as 'school connectedness'). Different components of school climate can be categorized into four main areas: safety, teaching and learning, relationships, and environmental-structural.¹⁰ For example,

a positive school climate may be one where students feel safe to voice their opinions (safety), the quality of teaching is high (teaching and learning), there is respect for diversity (relationships), and the school is of adequate size (environmental-structural). Although the concept of school climate is often assessed using individual perceptions, school climate is a universal condition that influences all individuals within the school (or a ‘group phenomenon’). Research on positive school climates has existed for over 100 years and has shown clear relationships with higher academic achievement, reduced violence, lower absenteeism, and decreased depressive symptoms.¹⁰

Many different scales have been developed and used to assess school climate, and they are all very similar (each addressing the four areas of school climate mentioned earlier) and have been subject to extensive validation efforts.¹¹ Many studies using data from the National Longitudinal Study of Adolescent Health (e.g., Brookmeyer et al¹², Dornbusch et al¹³) and the Health Behaviour in School-aged Children (HBSC) Study (e.g., Saab and Klinger¹⁴, Freeman et al¹⁵) use very similar questionnaire items to assess student perceptions of safety, connectedness, and authoritative structure.¹¹ This thesis uses a school climate scale based upon items from the Canadian HBSC study, which reflect aspects of teacher support¹⁶ and school capacity (**Appendix B**).

This thesis will assess school climate as an environmental risk factor and assess its potential interactions with an individual risk factor (multiple risk behaviour). With the success that previous environmental interventions have had (over interventions targeted at proximal risks) in reducing injury,¹⁷ this thesis will evaluate school climate as a strong environmental influence of school injury and revisit its relevance as a necessary target for public health intervention.

2.3 Adolescent Risk Behaviour

Adolescent development is marked with a number of physical and psychosocial changes that bridge the gap between life as a child and adulthood. Experimentation in novel activities, during and outside of school hours, is one way that adolescents obtain autonomy from their parents and is understood as a normative function of social development.¹⁸ However, this process can involve behaviours that

present varying degrees of risk towards sustaining an injury at school. Participation in high-risk behaviours remains an important area of research to understand the potential acute and then long-term health consequences of such actions.

There are numerous definitions of risk behaviour that stem from different branches of study – psychology, sociology, or epidemiology.^{19,20} Broadly speaking, in health science research, risk behaviours are ones that compromise the successful psychosocial and/or physical development of adolescents.²¹ More specifically, epidemiological research focuses on two forms of adolescent risk – risk factors and risk behaviours. Risk factors are individual or environmental antecedents of risk behaviours. For example, poverty could be a risk factor for poor eating habits, a potential risk behaviour. Conceptual frameworks of potential relationships between risk factors and behaviours have existed for over 40 years and provide an important distinction between the two concepts.²² This thesis will only consider risk behaviours and will evaluate the effect that those have on the likelihood of developing school injuries.

Many different risk behaviours have been shown to increase the likelihood of morbidity and mortality among children and adolescents.²³ However, in the health sciences the risk behaviours measured typically fall into one of six domains outlined by the US Centers of Disease Control and Prevention (CDC)¹⁹: (1) Behaviours that increase the risk of injury or displaying violence, (2) Sexual behaviours that increase the risk of acquiring a sexually transmitted infection or unintended pregnancy, (3) Smoking cigarettes, (4) Alcohol consumption and illicit substance use, (5) Unhealthy dietary patterns, and (6) Physical inactivity. These domains were established because of extensive evidence that, independently, they are major contributors to disease, injury, and death among youths. Although some of these domains may be more directly related to injury than others, this thesis will consider behaviours in all six domains.

2.3.1 Multiple Risk Behaviours

Risk behaviours have been studied extensively as individual factors, but there is little known about the concept of risk behaviours as a latent factor made up of a composition of separate behaviours.²⁴ A latent factor is a structure or concept that cannot be observed (i.e., risk behaviour), but can only be

inferred upon based on measures of proximal and observable outcomes (i.e., illicit substance use). The study of risk behaviour among adolescents may benefit from the conceptualization of risk as a composite measure of individual behaviours. First, studies on risk behaviours have shown an increase in the likelihood of sustaining injury as the number of independent risk behaviours increase. This dose-response association suggests an additive relationship, which supports the concept of studying risk-taking compositely, instead of as independent and separate behaviours.²³ Second, risk behaviours often cluster together. Therefore, to study the concept of risk-taking, it is necessary to consider the different behaviours that contribute to that concept collectively.²⁵ Third, research from the behavioural sciences suggests that interventions aimed towards a single risk behaviour have subsequent effects on other risk behaviours.²⁴ This suggests a complex interaction between risk-taking factors and provides additional support for the need to study these behaviours collectively and in composite scales.

The clustered and inter-related nature of individual risk behaviours relates too to Problem-Behaviour Theory, which suggest that individual and environmental factors (i.e., risk factors) act as instigating or protective factors for several risk behaviours simultaneously.²² Jessor and Jessor suggested that the factors that give rise to any particular risk behaviour could actually develop multiple risk behaviours concurrently – what they refer to as a “risk behaviour syndrome”.²² To study a latent factor such as ‘risk behaviour syndrome’, questionnaire items (on risk behaviours) are compiled from surveys to assess an individual’s degree of personal comfort or propensity to engage in risk-taking. This is done through an evaluation of the number of risk behaviours that an adolescent participates in (assuming that they are aware of the risks associated with their actions). Therefore, a scale measuring an individual’s propensity to perform a variety of risk behaviours represents an attempt to effectively measure their level of risk tolerance.

2.3.2 ‘Multiple Risk Behaviour’ Scales

A variety of different scales and measures have been developed to assess multiple risk behaviours as a latent factor. Scales of risk-taking typically include the majority of the behavioural domains

mentioned previously.²³ Prior studies have either developed a new scale using exploratory factor analysis or cited ones created by others and performed a confirmatory factor analysis to check the scale's validity. However, existing studies have rarely had the sample size to perform both types of factor analyses on their data, which limits the reliability of their scale. In response, this thesis will be based on an analysis with a student population of adequate sample size to develop a new multiple risk scale (using exploratory factor analysis) and also test its construct validity (using confirmatory factor analysis).

One of the limitations of developing scales through factor analysis is that it is often difficult to compare studies as they use different items that contribute to scales describing multiple risk behaviours.²⁴ To my knowledge, there is no standardized questionnaire, developed through the opinions and consensus of experts, which develops a single measure of an adolescent's level of risk behaviour. The current state of literature on adolescent risk behaviours generally agree that alcohol consumption and illicit substance use, risky sexual behaviour, smoking, and aggression are important facets that should be considered.^{23,26} However, few risk scales include those four areas, and even fewer include all six domains identified by the CDC.¹⁹ This thesis proposes following the framework of including all six risk behaviour domains identified by the CDC in the development of a measure of multiple risk behaviour. By including survey items from all six domains in exploratory factor analysis, risk behaviour measures will be comprehensive and promote the standardized measure of risk behaviour in future studies.

In addition, many of the questionnaire items included in recently published multiple risk scales have been the same as those used in scales developed almost 30 years earlier (e.g., Jessor and Jessor²², de Looze et al²⁷). This is problematic as many of the risky activities available to adolescents today are different than those from the past. The inception of eCigarettes (smokeless electronic nicotine pipes), the widespread consumption of caffeinated energy drinks, and the increase in sedentary activity represent only a few of the emerging areas of risk that currently affect adolescents. Independently, these behaviours and lifestyle choices have been shown to be associated with injury and disease.²⁸⁻³⁰ Recent studies on perceptions of these risk behaviours are alarming and show that some adolescents perceive a false sense of relative safety in these activities compared to other long-standing risky behaviours.³¹ These emerging risk

behaviours should be included in contemporary scales of multiple risk behaviour to (1) accurately reflect contemporary trends, and (2) to make the scale sensitive to individuals with more moderate tolerances of risk behaviours.

2.3.3 Measures of ‘Multiple Risk Behaviour’ and Injury among Adolescents

Previous research examining the relationship between multiple risk behaviours and injury typically focus on the classical behaviours associated with the stereotypical delinquent adolescent (**Table 1**). These measures of multiple risk behaviour are often created using theoretical ideas alone and have no real empirical basis.^{32,33} However, existing studies generally show that there is a strong relationship between participation in one or more of these “classical” risk behaviours, and an increased risk of injury. A study by Pickett et al showed a clear dose-response relationship between the participation of risk behaviours and the likelihood of injury.³⁴ Several others measuring multiple risk behaviour using some composite measure were also able to find positive relationships with psychosomatic symptoms,³⁵ general injuries in home and school settings,^{15,36} as well as fighting-related,³⁷ and head and neck injuries.³⁸ However, no association was observed when evaluating multiple risk behaviour and injuries resulting from physical activity.

Current research on the relationship between multiple risk behaviours and injury is generally well represented among the Canadian adolescent population. Although research on relationships between risk behaviour and adolescent injury also exist in other countries and contexts, the majority do not evaluate risk behaviour as a composite measure.³⁹⁻⁴¹ Although empirical measurements of related risk behaviours are beginning to emerge in the literature,⁴² the use of these multiple risk behaviour scales has not gained traction in injury research. Outside of Canada, studies either evaluate associations between independent risk behaviours and injury,³⁹ or use alternative measures of multiple risk behaviour that are not necessarily associated with health science research (e.g., theft, sneaking out of the house, and not waiting for the signal before crossing the road).^{40,43} While this thesis focuses on health-related risk behaviours, studies using these alternative measures of multiple risk behaviour also show positive associations with injury

Table 1. Current research on the relationship between multiple risk behaviour and injury among adolescents.

Authors and Publication Date	Source and Time of Data	Study Participants	Risk Behaviors Considered	Injury Types	Major Outcomes
Freeman et al ¹⁵ , 2011	HBSC Canada (2005-2006)	11-15 years	<i>Health Risk Behaviour</i> (smoking, drunkenness, non-use of seatbelts, cannabis use, other drug use)	Serious Injuries	<ul style="list-style-type: none"> • Significant association observed between multiple risk behaviours and serious injuries. • Multiple risk behaviours may mediate the relationship between negative home environments and serious injuries.
Koven et al ³⁸ , 2005	HBSC Canada (1997-1998)	11-15 years	<i>Lifestyle Risk</i> (available drug use; alcohol use; smoking; less available drug use; truancy) <i>Psychological Risk</i> (life satisfaction; loneliness; self-confidence; perception of self-health; parental influence)	Head and Neck Injury	<ul style="list-style-type: none"> • Association observed between <i>Lifestyle Risk</i> and head and neck injury. • No association found between <i>Psychological Risk</i> and head and neck injury.
Pickett et al ³⁴ , 2002	HBSC Canada (1997-1998)	11-15 years	Smoking, Drunkenness, Drug use, Seatbelt use in a car, Bike helmet use, Arguments with parents, Bullied others	All Injuries and Specific Sub-Types (e.g., sports, school)	<ul style="list-style-type: none"> • Significant association between participation in 7 risk behaviours and injury (OR = 4.11; 95% CI = 3.04-5.55). • Significant gradient of injury risk as the number of risk behaviours increases.
Pickett et al ³⁷ , 2002	HBSC International: 12 Countries (1997-1998)	11-15 years	<i>Multiple Risk Behaviour</i> (smoking, drunkenness, non-use of seatbelts, bullying others, excess time with friends, truancy, alienation at home and school, poor diet)	All Injuries	<ul style="list-style-type: none"> • Consistent internationally observed gradient of injury risk as the number of risk behaviours increases. • The same gradient is also observed when considering serious injuries specifically.
Pickett et al ³⁶ , 2006	HBSC Canada (2001-2002)	11-15 years	<i>Multiple Risk Behaviour</i> (smoking, drunkenness, non-use of seatbelts, cannabis use, other drug use, non-condom use)	Home and School Injuries	<ul style="list-style-type: none"> • Gradients of association observed between the extent of adolescent risk behaviour and the occurrence of injury.
Raman et al ³³ , 2009	HBSC Canada (2001-2002)	11-15 years	<i>Multiple Risk Behaviour</i> (smoking, drunkenness, non-use of seatbelts, cannabis use, other drug use, non-condom use)	All Injuries	<ul style="list-style-type: none"> • Disabled students engaging in multiple risk behaviours have a higher likelihood of injury than their nondisabled peers.
Janssen et al ³² , 2007	HBSC Canada (2001-2002)	11-15 years	<i>Multiple Risk Behaviour</i> (smoking, drunkenness, non-use of seatbelts, cannabis use, other drug use, non-condom use)	Physical Activity Injuries	<ul style="list-style-type: none"> • No observed gradients of association between participation in multiple risk behaviours and physical activity injuries.

and may provide some indication that different forms of adolescent risk-taking may be related to injury.⁴³

Adolescent risk behaviour can manifest in ways outside of the stereotypical framework of the “typical delinquent” as suggested by the variety of domains outlined in the CDC risk framework.¹⁹ Early evidence of alternative conceptualizations of multiple risk behaviour has recently emerged,⁴² however, no study has evaluated the relationship between these risk behaviour clusters with injury. This thesis will empirically develop measures of multiple risk behaviour considering all domains of the CDC risk framework and will be able to determine whether different manifestations of risk behaviour are associated with injury or other negative health outcomes.

2.3.4 Development and Use of the CDC Risk Behaviour Framework

The CDC risk behaviour framework was initially developed in 1992 to assess the adolescent health behaviours associated with the HIV epidemic in the United States in the 1980s.⁴⁴ Since then, it has grown to encapsulate a variety of other behaviours associated with adverse or unintended health outcomes among American youths. The six domains of risk behaviour in the framework were decided upon based on extensive research linking behaviours within each category to the leading causes of morbidity and mortality, as well as the consensus of scientific experts.⁴⁴ The Youth Risk Behaviour Survey is administered biennially and is currently used by regional government agencies for a variety of purposes including an assessment of the prevalence of risk behaviours, as well as the design of new programs and legislation to address areas of emerging concern.⁴⁵

It is now known that risk behaviours develop and occur in clusters among adolescents,²¹ yet surveillance, intervention programs, and research remain focused on these individual domains. Examples of some of the programs developed in response to surveillance data from the Youth Risk Behaviour Survey are: the Montana Tobacco Use Prevention Program (targeting smoking cessation) and the Massachusetts Alliance on Teen Pregnancy (addressing healthy relationships and sexual behaviours).⁴⁵ Research has also used this framework to study the determinants of individual risk behaviour domains, as well as associated health outcomes.^{46,47} The CDC risk domains represent clear categories of adolescent

problem behaviour. However, there is evidence that risk behaviours are not isolated into these domains and that there is a need for research to empirically evaluate the structure of these domains to assess the appropriateness of domain-specific surveillance, intervention programs, and research.⁴² Improved understanding of the inter-related nature of risk behaviours will allow research to effectively identify possible risk factors for future preventive intervention.

2.4 The Concept and Use of Population Health Theory

The combined study of individual and contextual risk factors is a concept that stems from hypotheses that suggest multiple levels of causation for injury and disease. This thesis will be grounded in the Public Health Agency of Canada's 'Population Health Framework', which suggests that there are interactions between an individual's underlying risk for injury related to themselves and their behaviours, and the inherent risks based on the environment that those individuals live in.⁴⁸ Research on individual and proximal risk factors (i.e., genetic and behavioural) make up a large proportion of all epidemiological literature. However, injury prevention efforts based on these 'proximal risk factor models' have seen mixed results – possibly due to their interventions aimed at down-stream and highly differentiated risk factors.^{17,49} In response, research on environmental contributions of disease is growing (i.e., social capital and school climate) and some have argued that such research approaches address more up-stream determinants of disease risk.⁴⁹ Studies showing that environmental factors play a part in injury risk provide support for theories suggesting a necessary combination of individual and environmental factors to make up a sufficient cause for injury or disease.⁴⁹

Although research on environmental and individual risk factors of disease continues to grow, there is only limited research on the relationships that each of those levels of risk has on each other.⁵⁰ Few studies have attempted to assess both the individual and contextual contributions of injury, as well as the interactive effects that they may have on injury risk. Studies that have considered both levels of risk have seen significant interactive effects between individual and environmental risk factors – demonstrating that both levels act synergistically to trigger disease episodes or injury events.¹⁴ The growing emphasis on

environmental risk factors is also bolstered by empirical evidence that intervention efforts aimed specifically towards environmental risk factors are more effective than individualized programs in some situations.⁵¹

The ‘Population Health Framework’s focus on individual and environmental disease risk will be used in this thesis to develop a better understanding of the etiology of school injury and to provide an effective outlet for future contextual intervention programs. To evaluate the individual and environmental risk contributions of school injury, this study will evaluate the individual risks associated with adolescent risk behaviour, as well as potential interactions between individuals and their school’s social environment (**Figure 1**).

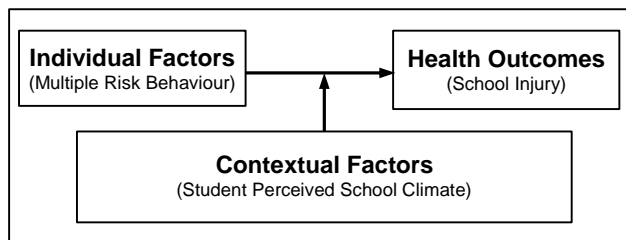


Figure 1. Conceptual Model based on Public Health Agency of Canada Population Health Framework.⁴⁸ Risk-taking behaviours have been shown to increase the risk of school injury.³⁶ School-based contextual factors may modify the relationship between risk-taking behaviours and school injury. This thesis aims to evaluate this relationship in a Canadian setting while considering the potential modifying effect of a contextual factor, school climate.

2.5 Study Rationale

School injury rates are high and typically result in enormous and long-lasting physical and economic burdens. This thesis will be the first to develop a new measure of multiple risk behaviour, grounded in the framework established by the CDC, to effectively measure both new and long-standing risk behaviours. By following the ‘Population Health Framework’, this study will evaluate relationships between individual factors (risk behaviour) and school injury outcomes, while considering school-based contextual factors simultaneously as a potential effect modifier. Such analyses could provide evidence in support of school-based population health intervention programs aimed at reducing the occurrence of injury among students at school.⁵² Development of new measures of multiple risk behaviour may also inform future research and policy intervention to address the full complement of behaviours within a given cluster, which some have suggested to be a more effective means of risk behaviour attenuation.⁵³

2.6 References

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Chapter 3

Adolescent Risk Taking in Canada: A contemporary empirical study of the CDC framework

3.1 Abstract

Importance: Although risk behaviours correlate strongly with the occurrence of injury among adolescents, and psychological theory on risk behaviour development has progressed for over 30 years, conceptualizations of how such behaviours inter-relate remain relatively unchanged and incomplete.

Objective: Based upon an empirical analysis, to revise an existing framework of risk behaviour from the US Centers of Disease Control and Prevention (CDC) by incorporating lessons from contemporary Problem Behaviour Theory.

Design, Setting, and Participants: The data source was the 2014 Canadian Health Behaviour in School-aged Children study – a World Health Organization collaborative cross-national study. Students completed confidential questionnaires in school classrooms. HBSC elicited information on a variety of health risk behaviours and outcomes. Our analysis used responses from 17,428 students from Grades 6-10 with representation from all provinces and territories across Canada.

Main Outcome Measure: Items describing risk behaviours in the questionnaire were identified and categorized according to six domains outlined in the CDC framework. Exploratory and confirmatory factor analyses were used to identify and validate latent constructs of risk behaviour participation. Empirically derived clusters of risk behaviour were then compared against the six domains proposed by the CDC framework to evaluate its real world utility.

Results: Three empirically derived clusters of risk behaviour emerged: 1) *Overt Risk Taking* (i.e., alcohol consumption, smoking, and energy drink consumption), 2) *Active Healthy Lifestyle Detriment* (i.e., sedentary behaviours and unhealthy snacking), and 3) *Passive Healthy Lifestyle Detriment* (i.e., physical inactivity and low fruit and vegetable consumption). The empirically derived risk behaviour categories were consistent across different grade groups (6-8, 9-10) and were validated against a separate subset of the study sample.

Conclusions and Relevance: The derived risk behaviour clusters each draw from multiple domains within the CDC framework, and demonstrate that the domains are closely related to one another. Our

findings support a new way of conceptualizing multiple risk behaviours among adolescents by highlighting the breadth and diversity of risk behaviour engagement. Future research and preventive interventions should potentially target the complement of behaviours present within each of our three newly developed categories.

3.2 Introduction

Adolescent risk-taking behaviours are well-established causes of illness and injury.¹ ‘Problem Behaviour Theory’ is foundational to modern adolescent risk research and suggests that adolescents develop risk-taking behaviours in related groups based on a variety of upstream determinants (or risk factors).² Such risk behaviours cluster together in predictable patterns within populations of young people.³ Research and ongoing surveillance efforts in the field of adolescent risk-taking should therefore focus on these behaviours, both individually and in related groups, to inform prevention efforts aimed specifically at adolescents.

More than two decades ago, the US Centers of Disease Control and Prevention (CDC) created a risk behaviour framework that can be used to classify adolescent risk behaviours and how they naturally cluster together.⁴ This framework provides one standard paradigm for the applied study and surveillance of such behaviours.^{5,6} The framework categorizes risk behaviours across six domains that are associated with leading causes of morbidity and mortality among American youths: smoking cigarettes, alcohol and illicit substance use, high-risk sexual behaviour, high-risk manifest behaviour, unhealthy dietary patterns, and physical inactivity.⁴ These domains, while informed by peer-reviewed literature,⁴ were established by consensus and have seldom been subject to rigorous population-based psychometric examinations. Contemporary risk behaviours have also not been incorporated into the framework. Since this framework is relied upon for population-based and clinical work, confirmation and refinement of this framework and its six components may provide further insights for preventive intervention.

While there is a rich literature available that describes inter-relationships between adolescent risk behaviours and their consequent relationships with injury (e.g., Schane et al⁷, Yarber and Parrillo⁸, and Lytle⁹), such studies rarely considered the full complement of the domains of risk behaviours outlined within the CDC framework. As a consequence, there may be an incomplete conceptual understanding of adolescent risk behaviours and how they tend to develop and occur concurrently. For example, a large body of literature on adolescent risk taking focuses on behaviours found in the stereotypical delinquent adolescent (i.e., alcohol and drug use, cigarette smoking, and high-risk sexual behaviours) (e.g., Lindberg et al¹⁰ and Turner et al¹). Although these behaviours are suggestive of a high-risk lifestyle, they may also be related conceptually (and mathematically) to risk behaviours from other domains. In addition, there may also be other expressions of risk behaviour, including new ones (e.g., e-cigarettes, caffeinated energy drinks¹¹), which are not encompassed by these established risk behaviours. The CDC framework provides some indication of these additional domains of adolescent risk related to illness and injury.⁴ Therefore, there is a need for an empirical analysis to examine the inter-relationships between the six CDC risk domains within a population-based study. In addition, most of the existing empirical research in this field has been concentrated in the United States (e.g., Riesch et al¹² and Basen-Engquist et al¹³), and there too is a need for analogous research in other countries and contexts including Canada.

Variations in the engagement of young people in risk-taking behaviours within different groups are also important to document in order to best inform and target preventive initiatives. Two common demographic covariates worthy of focused study are socio-economic status (SES) and biological sex. Although relationships between these demographic covariates and individual risk behaviours are well studied,¹⁴⁻¹⁶ there is little evidence examining the clustering of risk-taking behaviours within such groups. Of the existing research, it has typically focused on stereotypical delinquent risk behaviours with evidence of variations in risk-taking across different levels of SES and an increased participation in these behaviours among males.¹⁷ Further evaluation of these possible upstream determinants and their relations with clustered risk-taking is therefore warranted.

We had the opportunity, through robust statistical analyses that involve both exploratory and confirmatory methods and a large population-based study of Canadian adolescents,¹⁸ to evaluate this framework in a formal empirical analysis. Our objectives were: 1) to analytically test the relationships between adolescent risk behaviours from all six distinct domains, as outlined by the CDC, and 2) to create and validate new measures of clustered risk behaviours in a Canadian adolescent population.

3.3 Methods

Study Base and Sampling

This study is based on Canadian records (an interim dataset of N = 17,428) from the Health Behaviour in School-aged Children Study (HBSC), a World Health Organization collaborative cross-national study.¹⁸ Cycle 7 of the HBSC study in Canada evaluated health outcomes, attitudes, and behaviours using a confidential questionnaire administered to students from 227 schools during the 2013-14 academic year. HBSC in Canada follows an international sampling protocol. Classes within selected schools were selected for participation using a weighted probability technique to ensure proportional representation based on the following demographic characteristics: geographical location, language of instruction, religion, and community size. The target age range of students was 11-15 years, Grades 6 to 10 in Canada.¹⁹ Elementary school students were given a condensed survey that omitted questions of a more sensitive-nature (i.e., illicit drug use and sexual behaviour). Students enrolled in private, special needs, on-reserve, or faith schools (other than publicly funded Roman Catholic schools) were not included; these represent <7% of the Canadian student population in this age range.¹⁹

Measures of Risk Behaviour

As per existing precedents, we defined risk behaviours as “voluntary behaviours having known health consequences that can threaten an individual’s successful physical and/or psychosocial development”.² All risk behaviours that met this definition and were measured in Cycle 7 of the Canadian HBSC were identified. We then categorized each identified risk behaviour (27 identified in total)

according to the six domains of risk outlined in the CDC framework.⁴ In order to standardize our approach to classification and subsequent factor analysis for categorical variables, we re-coded each of the 27 items into three broad categories: none/minimal, moderate, and frequent (engagement in the risk behaviour) (see **Table 1**).²⁰

Key Covariates

Information about student grade level and biological sex were obtained from the HBSC questionnaire. Measures of SES were developed using an existing and validated HBSC Family Affluence Scale.²¹ The Family Affluence Scale consists of four questions asking students about the number of motor vehicles and computers that the family owns, whether the student has their own bedroom, as well as the number of trips that the family takes for vacation. Students were assigned a low, moderate, or high level of SES based on cutoffs suggested by the HBSC international protocol.²¹

Statistical Analyses

Latent risk constructs were identified from the list of risk behaviours and then validated using exploratory and confirmatory factor analyses, respectively.²² A split-sampling method was followed, with the study sample randomly divided in half using a simple random sampling technique (equal probability without replacement). Separate exploratory and confirmatory factor analyses were then performed for each of the two grade groups (6-8, 9-10) due to the differences in available measures of risk behaviours in the two groups. Common factors in the exploratory analyses were extracted using iterated principal axis factoring with promax rotation. Factor loadings below 0.30 were suppressed.²³ Factor interpretability, scree plots, and parallel analyses were used to specify the number of factors to include in the final model.²⁴ Confirmatory factor analysis using maximum likelihood estimation was then used to validate the common factor structure. Root Mean Squared Error of Approximation (RMSEA), Standardized Root Mean Square Residuals (SRMR), and Adjusted Goodness of Fit Index (AGFI) were used to evaluate model fit.²⁵

Measures of general risk behaviour were created for each common factor using weights from the exploratory factor analysis. To maximize power, missing responses to individual risk behaviours were imputed using mean scores for students with 30% or fewer missing responses under a single common factor. Weighted scores for each common factor were split into tertiles to represent low, medium, and high risk relative to their peers for the behaviours associated with that common factor. Levels of risk behaviour engagement were also evaluated within groups of young people defined by sex and different levels of SES using Chi-squared tests. All analyses in this study were conducted in SAS (Version 9.4, SAS Institute, Cary, NC).

3.4 Results

Sample Population

Of the 17,428 responses available for study, 7,785 represented students in Grades 9-10 and 9,643 were students in Grades 6-8. The proportion of students identified as high-risk under each of the risk behaviours included in the final model can be found in **Table 2**.

Exploratory and Confirmatory Factor Analysis

After consideration of the available 27 risk behaviours, a three-factor solution emerged from the exploratory factor analyses within both grade groups. The final model in both grade groups had an independent cluster solution. Eigenvalues for all common factors in the models were above the 90% confidence intervals from the parallel analyses, suggesting that variances explained by the factors were better than a chance finding. Final eigenvalues for the Grade 9-10 model were 5.02, 2.44, and 1.32 (N = 2,338). For Grade 6-8 students findings were consistent; the final eigenvalues were 3.15, 2.02, and 1.24 (N = 3,423). Some student observations were not used because of missing responses to risk behaviour questions on the HBSC questionnaire.

Based on similar results from exploratory analyses for both grade groups, the three risk behaviour categories were labeled together based on a general conceptual understanding of the behaviours that

emerged from their respective exploratory factor analyses (**Table 3 and Table 4**). The first common factor showed behaviours associated with substance use and externalizing risk taking such as fighting, bullying, and risky sexual behaviour. We called this category ‘Overt Risk Taking’. The second factor grouped sedentary screen-time activities together. Among Grade 6-8 students specifically, these sedentary behaviours also grouped together with unhealthy snacking behaviours (i.e., potato chip and soda consumption). Because of the proactive actions that compromise healthy, balanced lifestyles, we called this category ‘Active Healthy Lifestyle Detriment’. The third factor for Grade 9-10 students identified behaviours associated with an avoidance of nutritious food (such as fruits and vegetables) and physical inactivity indicators – we called this category ‘Passive Healthy Lifestyle Detriment’. Cronbach’s alpha values calculated for each of the risk behaviour categories in both grade groups were all above 0.70 suggesting good levels of internal consistency.

In both grade groups, modest correlations were observed between common factors. *Overt Risk Taking* was marginally correlated to both *Active Healthy Lifestyle Detriment* (Grade 9-10: $r = -0.023$; Grade 6-8: $r = 0.095$) and *Passive Healthy Lifestyle Detriment* (Grade 9-10: $r = 0.120$; Grade 6-8: $r = 0.109$). There were positive correlations of moderate strength between *Active Healthy Lifestyle Detriment* and *Passive Healthy Lifestyle Detriment* in both grade groups (Grade 9-10: $r = 0.277$; Grade 6-8: $r = 0.331$). Overall, these correlations suggest that these three factors are quite distinct from one another.

Confirmatory factor analyses suggested that the Grade 9-10 (SRMR = 0.076, RMSEA = 0.111, AGFI = 0.778, N = 2 499) and the Grade 6-8 final models (SRMR = 0.075, RMSEA = 0.105, AGFI = 0.820, N = 3 608) both showed modest but acceptable fit.²⁵

Relationship with Covariates: Sex and SES

Trends of risk behaviour between sexes were inconsistent across different risk categories and grade groups (**Table 5**). However, there were noticeable trends of risk behaviour across different levels of SES. In the *Overt Risk Taking* and the *Passive Healthy Lifestyle Detriment* categories, participation in risk behaviours decreased as family SES increased. This relationship was observed consistently across grade

groups. No statistically significant relationship between risk behaviour and SES was found in the *Active Healthy Lifestyle Detriment* category.

3.5 Discussion

This study provides a contemporary examination of risk-taking in Canadian adolescents and determines if in fact individual risk behaviours cluster together as per the domains of the well-established CDC framework.⁴ We found that three categories of clustered risk behaviour emerged that encompassed all six domains of risk outlined by the CDC framework. Our findings were fairly consistent across two broad developmental periods (Grades 6-8 and 9-10), although the items available to measure adolescent risk-taking varied in these two groups.

The CDC's survey of adolescent risk behaviours was initially created to evaluate and monitor the domains of behaviour most closely associated with known leading causes of morbidity and mortality.⁴ At the time, research on the adverse health outcomes of single risk behaviours was predominant in the literature,⁷⁻⁹ which in turn led to the development of the six isolated domains of risk behaviours that still exist in the framework today. Currently, these six domains are still used by US government agencies to monitor adolescent risk behaviours for targeted interventions.²⁶ By incorporating the lessons of Problem Behaviour Theory² and identifying three instead of six distinct categories of risk behaviour using contemporary population-based data, our study suggests the need for a refinement of the CDC framework and its application.

Our approach to conceptualizing risk behaviour recognizes the complex relationships that exist between them, as well as their possible joint effects on disease etiology. The items indicated by the CDC domains are intimately related in interpretable and potentially unexpected ways consistent across grade groups. As a result, these behaviours should be observed and measured collectively under each of the three categories in order to be properly understood and managed.

The three risk categories that were identified by factor analysis incorporated items that are well recognized within the adolescent health research literature. The *Overt Risk Taking* category largely encompasses behaviours found in traditional adolescent risk studies (e.g., Maggs et al²⁷ and de Looze²⁸). However, we believe the benefits of our analysis lie in the more contemporary expressions of risk-taking that were incorporated. For example, the inclusion of *energy drink consumption* and the *use of alternative tobacco products* highlight emerging areas of related risk that reveal either the true breadth of this category, or behaviours associated with more moderate risk tolerance that indicate early development of risk-taking in this domain. The *Active Healthy Lifestyle Detriment* and *Passive Healthy Lifestyle Detriment* categories show close relationships between diet and physical activity that have been well recognized in past research.²⁹ Yet our empirical distinction between these categories also supports studies that show that sedentary behaviour and physical inactivity may represent separate and distinct behaviours among adolescent populations.³⁰ Our study's risk categories represent measures of three separate manifestations of adolescent risk behaviour and were found to be robust through confirmatory analysis in a separate subset of our study population.

Lastly, our work completed a preliminary evaluation of SES and sex as possible risk factors of the risk behaviour categories that were derived in this study. We observed an inverse relationship between SES and risk behaviour participation in the *Overt Risk Taking* and *Passive Healthy Lifestyle Detriment* categories. Recognition of these relationships could suggest that SES is a strong and simultaneous determinant of multiple risk behaviours under the same category. However, the mechanism behind this relationship is unclear, and further research is needed to validate this relationship in different contexts before interventions are designed to target SES as a risk factor. Although studies evaluating risk behaviours in isolation should be used cautiously in the context of risk behaviour clusters, some evidence suggests that low SES may be associated with lower values towards preventive health care.³¹ Associations have been observed between low SES and lower seatbelt use³² as well as higher smoking prevalence,³¹ which may indicate a general form of apathy towards preventive healthcare and may include behaviours such as physical inactivity.

There are benefits and weaknesses to our new three-domain conceptualization of risk behaviours over the six-domain framework developed by the CDC. A major strength of the six-domain approach to adolescent risk behaviours is that it was based on the premise, supported by evidence,^{4,7-9} that each of the six domains has been associated with negative health outcomes in focused analyses. Second, the domains are very clear conceptually in the six-domain approach, perhaps making it simpler to classify risk behaviours. However, the three categories that were derived empirically in our analyses recognize the more complex relationships between risk behaviours that exist across domains. The three domain approach is perhaps more consistent with the way that adolescents behave socially. Each domain identifies distinct constructs of adolescent risk-tolerance that exist in the real world. More importantly, these domains have implications for the development and targeting of public health interventions that improve upon individual risk behaviour approaches, and clustered risk-behaviour approaches that have no empirical basis.

We therefore believe that our analysis compliments the work of the investigators who developed the CDC framework, and extends it by being one of the first analytically tested models of the different ways that adolescents choose to participate in risky behaviour. This study identified three different ways that adolescents demonstrate high-risk behaviours – each presumably having their own upstream determinants and downstream health consequences. Further research is now needed to confirm these three risk behaviour categories in other study populations and contexts, and to evaluate the health outcomes and risk factors associated with each distinct category. Future intervention programs could then target the risk factors of each category to address their associated negative health outcomes.

An obvious limitation of our study is its reliance on self-reported data. Although many steps were taken to emphasize the confidentiality of their responses,¹⁸ students may not have answered truthfully to all the questions due to social desirability biases. There were also higher rates of non-response for questions of a particularly sensitive nature, most notably those surrounding sexual behaviour. Further, since this study used an interim Cycle 7 dataset, there was lower representation from British Columbia and

the three Northern Territories of Canada. Statistical weights were also not yet available and each student response was given an equal weight of 1.0. Therefore, although this study has representation from all the provinces and territories of Canada, proportional estimates reported in this study are not representative of all Canadian adolescents.

3.6 Conclusion

This study used a large sample of Canadian adolescents to analytically test the six-domain framework of risk behaviour outlined by the US CDC.²⁶ Our empirical analysis, which included both exploratory and confirmatory factor analytic techniques, found that adolescent risk behaviour patterns are not isolated to the domains outlined by the CDC. Three categories of risk behaviours emerged from the six-domain framework: 1) *Overt Risk Taking*, 2) *Active Healthy Lifestyle Detriment*, and 3) *Passive Healthy Lifestyle Detriment*. These categories build on the six-domain framework outlined by the CDC, and have important implications to research and intervention efforts aimed at preventing adolescent illness and injury. Future research should utilize this new framework of adolescent risk behaviour to study their upstream determinants, as well as their joint causes of negative health outcomes.

3.7 Acknowledgements

Author's Contributions

Mr. Kwong had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: All authors.

Acquisition, analysis, or interpretation of data: All authors.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Kwong

Study supervision: Pickett, Klinger

Conflict of Interest Disclosures

None declared.

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Table 1. Initial set of risk behaviours from the HBSC used for exploratory factor analysis. Coding of relative risk for each of the risk behaviours is also included.

Initial Set of Risk Behaviours	None/Minimal Engagement	Moderate Engagement	Frequent Engagement
CDC Domain 1: Smoking Cigarettes			
1.1 Number of days they smoked cigarettes in their life	Never	1-29 Days	30+ Days
1.2 Alternative tobacco products (e.g., e-cigarette, flavoured tobacco...) [†]	Never used any	Used one once or more	Used several once or more
CDC Domain 2: Alcohol and Illicit Substance Use			
2.1 Frequency of alcohol consumption (e.g., beer, wine, cider...) [†]	Never drank any	Rarely	Every month - Every day
2.2 Number of drinks per typical event	Never drank	Less than one - One drink	2+ Drinks
2.3 Number of times they got drunk in their life*	Never	Once	2+ Times
2.4 Frequency of binge drinking in the last year*	Never drank - Never binged	Less than or once a month	2-3 times a month - Daily
2.5 Number of days they used cannabis in their life*	Never	1-5 Days	6+ Days
2.6 Number of times they used hard drugs (e.g., ecstasy, solvents, pain medication...) [†]	Never used any	Used one once	Used several once or more
CDC Domain 3: High-Risk Sexual Behaviours			
3.1 Lifetime sexual history and use of contraceptives**	Never had sex	Had sex using contraception	Sex without contraception
CDC Domain 4: High-Risk Manifest Behaviours			
4.1 Number of times they got into a fight in the last year	No fights	Once	2+ Times
4.2 Frequency of personal bullying behaviours on others	No bullying	Once - 3 times a month	Once a week or more
4.3 Frequency of helmet use while riding a bicycle	Always	Sometimes - Most of the time	Never
4.4 Frequency of helmet use while in an off-road vehicle	Always	Sometimes - Most of the time	Never
CDC Domain 5: Unhealthy Dietary Pattern			
5.1 Frequency of pop/soda consumption in a typical week	Never - Once a week	2-4 times a week	5-6 times a week or more
5.2 Frequency of chip consumption in a typical week	Never - Once a week	2-4 times a week	5-6 times a week or more
5.3 Frequency of eating at fast food restaurants	Never - Less than 1 a month	Once - 3 times a month	Once a week or more
5.4 Frequency of sweet/candy consumption in a typical week	Never - Once a week	2-4 times a week	5-6 times a week or more
5.5 Frequency of energy drink consumption in a typical week	Never	Less than or once a week	2-4 times a week or more
5.6 Frequency of fruit consumption in a typical week	Once or more a day	2-6 times a week	Never - Once a week
5.7 Frequency of vegetable consumption in a typical week	Once or more a day	2-6 times a week	Never - Once a week
5.8 Frequency of orange vegetable consumption in a typical week	Once or more a day	2-6 times a week	Never - Once a week
CDC Domain 6: Physical Inactivity			
6.1 Hours watching TV or videos on a typical weekday	None - One hour	2-3 Hours	4+ Hours
6.2 Hours watching TV or videos on a typical weekend	None - One hour	2-3 Hours	4+ Hours
6.3 Hours playing video games on a typical weekday	None - One hour	2-3 Hours	4+ Hours
6.4 Hours playing video games on a typical weekend	None - One hour	2-3 Hours	4+ Hours
6.5 Number of days physically active for 60+ min. last week	6-7 Days	3-5 Days	0-2 Days
6.6 Number of days physically active for 60+ min. in a typical week	6-7 Days	3-5 Days	0-2 Days

Note: Coding within each level of risk may represent an aggregate of multiple questionnaire options.

*Grade 6-8 students are not asked these questions in the HBSC Study.

[†]Denote risk behaviours that are a composite measure combining multiple HBSC Study questionnaire items.

Table 2. Students in each risk level for all risk behaviours in the final exploratory model.

Final Set of Risk Behaviours	Frequency of Risk Behaviour Engagement						Missing
	None/Minimal		Moderate		Frequent		
	No.	Row %	No.	Row %	No.	Row %	
Grade 9-10 Students							
CDC Domain 1: Smoking Cigarettes							
Lifetime Smoking History	5756	(76.0)	1160	(15.3)	654	(8.6)	215
Use of Alternative Tobacco Products	5471	(72.4)	1144	(15.2)	934	(12.4)	236
CDC Domain 2: Alcohol and Illicit Substance Use							
Frequency of Alcohol Consumption	3159	(41.5)	2343	(30.8)	2104	(27.7)	179
Number of Drinks per Typical Event	3409	(45.4)	1418	(18.9)	2678	(35.7)	280
Lifetime Drunkenness History	4837	(63.7)	1822	(24.0)	934	(12.3)	192
Binge Drinking	4669	(64.5)	1678	(23.2)	887	(12.3)	551
Illicit Drug Use	6008	(79.4)	359	(4.7)	1199	(15.9)	219
Lifetime Cannabis Use	5511	(73.1)	533	(7.1)	1491	(19.8)	250
CDC Domain 3: High-Risk Sexual Behaviours							
Sex and Contraceptive Use	4747	(74.5)	1348	(21.2)	277	(4.4)	1413
CDC Domain 4: High-Risk Manifest Behaviours							
Physical Fighting	5475	(72.1)	1001	(13.2)	1123	(14.8)	186
Bullying Others	5413	(71.0)	2023	(26.5)	187	(2.4)	162
CDC Domain 5: Unhealthy Dietary Pattern							
Pop/Soda Consumption	4195	(54.9)	1724	(22.6)	1721	(22.5)	145
Chip Consumption	5276	(69.4)	1568	(20.6)	763	(10.0)	178
Energy Drink Consumption	5373	(69.8)	1721	(22.3)	609	(7.9)	82
Low Fruit Consumption	3127	(40.6)	3530	(45.8)	1044	(13.6)	84
Low Vegetable Consumption	2919	(38.4)	3542	(46.6)	1145	(15.1)	179
Low Orange Vegetable Consumption	1025	(13.3)	3406	(44.3)	3251	(42.3)	103
CDC Domain 6: Physical Inactivity							
Watching TV or Videos (Weekday)	2627	(35.8)	2875	(39.2)	1828	(24.9)	455
Watching TV or Videos (Weekend)	1602	(22.0)	2405	(33.0)	3293	(45.1)	485
Playing Video Games (Weekday)	3424	(46.7)	1923	(26.2)	1989	(27.1)	449
Playing Video Games (Weekend)	2592	(35.5)	1710	(23.4)	2992	(41.0)	491
Low Physical Activity (Typical Week)	2320	(30.3)	3798	(49.6)	1539	(20.1)	128
Low Physical Activity (Last Week)	2453	(33.9)	3599	(49.7)	1189	(16.4)	544
Grade 6-8 Students							
CDC Domain 1: Smoking Cigarettes							
Lifetime Smoking History	8767	(93.4)	473	(5.0)	144	(1.5)	259
Use of Alternative Tobacco Products	8664	(92.9)	454	(4.9)	211	(2.3)	314
CDC Domain 2: Alcohol and Illicit Substance Use							
Frequency of Alcohol Consumption	7213	(76.8)	1649	(17.6)	532	(5.7)	249
Lifetime Drunkenness History	8726	(93.2)	526	(5.6)	112	(1.2)	279
CDC Domain 4: High-Risk Manifest Behaviours							
Physical Fighting	6290	(67.3)	1398	(15.0)	1662	(17.8)	293
Bullying Others	6788	(72.8)	2361	(25.3)	176	(1.9)	318
CDC Domain 5: Unhealthy Dietary Pattern							
Pop/Soda Consumption	5780	(61.7)	1955	(20.9)	1633	(17.4)	275
Chip Consumption	6641	(71.3)	1705	(18.3)	972	(10.4)	325
Energy Drink Consumption	7800	(82.3)	1278	(13.5)	399	(4.2)	166
Low Fruit Consumption	4469	(47.0)	3967	(41.7)	1081	(11.4)	126
Low Vegetable Consumption	3798	(40.7)	3910	(41.9)	1615	(17.3)	320
Low Orange Vegetable Consumption	1508	(16.1)	4049	(43.1)	3841	(40.9)	245
CDC Domain 6: Physical Inactivity							
Watching TV or Videos (Weekday)	4054	(45.0)	3278	(36.4)	1677	(18.6)	634
Watching TV or Videos (Weekend)	2470	(27.5)	3217	(35.8)	3296	(36.7)	660
Playing Video Games (Weekday)	4612	(51.2)	2520	(28.0)	1869	(20.8)	642
Playing Video Games (Weekend)	3273	(36.5)	2456	(27.4)	3231	(36.1)	683
Low Physical Activity (Typical Week)	3655	(38.8)	4294	(45.6)	1479	(15.7)	215
Low Physical Activity (Last Week)	3935	(42.8)	4187	(45.5)	1081	(11.8)	440

Table 3. Exploratory factor analysis¹ on risk behaviours considering all domains in the US CDC risk framework in Grade 9-10 students. Values under each factor represent factor loadings.

Risk Behaviours	Factor 1 Overt Risk Taking	Factor 2 Active Healthy Lifestyle Detriment	Factor 3 Passive Healthy Lifestyle Detriment
Smoking Behaviour			
Lifetime Smoking History	0.67		
Use of Alternative Tobacco Products	0.70		
Alcohol and Illicit Substance Use			
Frequency of Alcohol Consumption	0.76		
Number of Drinks per Typical Event	0.77		
Lifetime Drunkenness History	0.84		
Binge Drinking	0.80		
Illicit Drug Use	0.35		
Lifetime Cannabis Use	0.70		
High-Risk Sexual Behaviours			
Sex and Contraceptive Use	0.53		
High-Risk Manifest Behaviours			
Physical Fighting	0.34		
Unhealthy Dietary Pattern			
Energy Drink Consumption	0.43		
Physical Inactivity			
Watching TV/Videos on a Screen (Weekday)		0.60	
Watching TV/Videos on a Screen (Weekend)		0.54	
Playing Video Games (Weekday)		0.74	
Playing Video Games (Weekend)		0.73	
Unhealthy Dietary Pattern			
Fruit Consumption			0.68
Vegetable Consumption			0.71
Orange Vegetable Consumption			0.52
Physical Inactivity			
Amount of Physical Activity (Typical Week)			0.50
Amount of Physical Activity (Last Week)			0.48
Eigenvalues	5.02	2.44	1.32
Cronbach's Alpha (Standardized)	0.88	0.77	0.71
Confirmatory Factor Analysis ² : RMSEA (90% CI)	0.111 (0.108, 0.113)		
Confirmatory Factor Analysis ² : SRMR	0.076		
Confirmatory Factor Analysis ² : AGFI	0.778		

¹Exploratory factor analysis using iterated principal axis factoring and promax rotation. Factor loadings lower than 0.3 were suppressed.

²Confirmatory factor analysis using maximum likelihood estimation.

Table 4. Exploratory factor analysis¹ on risk behaviours considering all domains in the US CDC risk framework in Grade 6-8 students. Values under each factor represent factor loadings.

Risk Behaviours	Factor 1 Overt Risk Taking	Factor 2 Active Healthy Lifestyle Detriment	Factor 3 Passive Healthy Lifestyle Detriment
Smoking Behaviour			
Lifetime Smoking History	0.71		
Use of Alternative Tobacco Products	0.70		
Alcohol and Illicit Substance Use			
Frequency of Alcohol Consumption	0.55		
Lifetime Drunkenness History	0.66		
High-Risk Manifest Behaviours			
Bullying Others	0.30		
Physical Fighting	0.33		
Unhealthy Dietary Pattern			
Energy Drink Consumption	0.48		
Unhealthy Dietary Pattern			
Pop/Soda Consumption		0.36	
Chip Consumption		0.30	
Physical Inactivity			
Watching TV/Videos on a Screen (Weekday)		0.63	
Watching TV/Videos on a Screen (Weekend)		0.59	
Playing Video Games (Weekday)		0.70	
Playing Video Games (Weekend)		0.70	
Unhealthy Dietary Pattern			
Fruit Consumption			0.57
Vegetable Consumption			0.59
Orange Vegetable Consumption			0.46
Physical Inactivity			
Amount of Physical Activity (Typical Week)			0.66
Amount of Physical Activity (Last Week)			0.65
Eigenvalues	3.15	2.02	1.24
Cronbach's Alpha (Standardized)	0.74	0.72	0.72
Confirmatory Factor Analysis ² : RMSEA (90% CI)	0.105 (0.103, 0.108)		
Confirmatory Factor Analysis ² : SRMR	0.075		
Confirmatory Factor Analysis ² : AGFI	0.820		

¹Exploratory factor analysis using iterated principal axis factoring and promax rotation. Factor loadings lower than 0.3 were suppressed.

²Confirmatory factor analysis using maximum likelihood estimation.

Table 5. Sex and SES distribution by level of risk category for both grade groups.

Level of Risk Category 1: Overt Risk Taking								
		Low Risk		Moderate Risk		High Risk		P-Value *
		No.	Row %	No.	Row %	No.	Row %	
Grade 9-10	Males	1280	(33.6)	1279	(33.5)	1254	(32.9)	0.025
	Females	1415	(35.9)	1217	(30.9)	1308	(33.2)	
	Low SES	74	(30.0)	75	(30.4)	98	(39.7)	0.001
	Mid SES	808	(32.8)	786	(31.9)	873	(35.4)	
	High SES	1541	(35.9)	1417	(30.4)	1331	(31.0)	
Grade 6-8	Males	1666	(35.1)	1344	(28.3)	1743	(36.7)	< 0.001
	Females	2516	(52.0)	1178	(24.3)	1145	(23.7)	
	Low SES	110	(33.5)	72	(22.0)	146	(44.5)	< 0.001
	Mid SES	1299	(41.3)	853	(27.1)	991	(31.3)	
	High SES	2424	(44.3)	1489	(27.2)	1565	(28.6)	
Level of Risk Category 2: Active Healthy Lifestyle Detriment								
Grade 9-10	Males	1188	(31.2)	1264	(33.2)	1361	(35.7)	< 0.001
	Females	1459	(37.0)	1369	(34.8)	1112	(28.2)	
	Low SES	83	(33.6)	74	(30.0)	90	(36.4)	0.008
	Mid SES	746	(30.2)	860	(34.9)	861	(34.9)	
	High SES	1406	(32.8)	1544	(36.0)	1339	(31.2)	
Grade 6-8	Males	1616	(34.0)	1423	(29.9)	1714	(36.1)	< 0.001
	Females	2042	(42.2)	1474	(30.5)	1323	(27.3)	
	Low SES	119	(36.3)	102	(31.1)	107	(32.6)	0.164
	Mid SES	1057	(33.6)	1024	(32.6)	1062	(33.8)	
	High SES	1990	(36.3)	1703	(31.1)	1785	(32.6)	
Level of Risk Category 3: Passive Healthy Lifestyle Detriment								
Grade 9-10	Males	1209	(31.7)	1348	(35.4)	1256	(32.9)	0.001
	Females	1375	(34.9)	1238	(31.4)	1327	(33.7)	
	Low SES	62	(25.1)	75	(30.4)	110	(44.5)	< 0.001
	Mid SES	668	(27.1)	825	(33.4)	974	(39.5)	
	High SES	1622	(37.8)	1415	(33.0)	1252	(29.2)	
Grade 6-8	Males	1572	(33.1)	1466	(30.8)	1715	(36.1)	0.207
	Females	1546	(32.0)	1572	(32.5)	1721	(35.6)	
	Low SES	74	(22.6)	82	(25.0)	172	(52.4)	< 0.001
	Mid SES	835	(26.6)	952	(30.3)	1356	(43.1)	
	High SES	1984	(36.2)	1812	(33.1)	1682	(30.7)	

Chapter 4

Assessment of contemporary risk behaviour scales and school climate as interactive determinants of school injury among Canadian adolescents

4.1 Abstract

Background: Relationships between individual risk behaviours and adolescent injury have been established. However, research shows that risk behaviours develop concurrently in predictable clusters. There is currently a paucity of research relating risk behaviour clusters to injury. We evaluated adolescent risk behaviour and school social climate as distinct and potential interactive determinants of school injury using population health theory to support our etiological thinking.

Methods: This study used the 2014 Canadian Health Behaviour in School-aged Children (HBSC) Study that has responses from 17,428 students in 227 schools across Canada. We evaluated three categories of adolescent risk behaviour: *Overt Risk Taking*, *Active Healthy Lifestyle Detriment*, and *Passive Healthy Lifestyle Detriment*. Direct relationships between risk behaviour and school injury, as well as ones modified by school social climate were evaluated using multiple logistic regression analyses.

Results: Young (Grades 6-8), overt-risk takers experienced an increased odds of general and specific subtypes of school injury (OR=1.61; 95% CI=1.30, 2.01). No observable relationships were observed among older students (Grades 9-10). School climate had inconsistent and variable influences and was not identified as an effect modifier. Different gradients of association were found between grade groups and across levels of school climate, suggesting age/grade group may in fact modify these relationships.

Conclusions: Relationships exist between risk behaviour categories and school injury. However, the potential etiological role of school climate is inconsistent and cannot be easily generalized across grade groups or types of school injury. Research and interventions should target upstream determinants of risk behaviour clusters and high-risk adolescent groups to prevent future school injury.

4.2 Introduction

Engagement in risk-taking behaviour is an established cause of injury within adolescent populations.¹ Risk behaviours are often considered individually in etiological studies (e.g., Yarber and Parrillo², Brook et al³) and preventive interventions,⁴ yet there is compelling evidence to suggest that they most naturally occur together in clusters.⁵ This phenomenon has been documented in what is now referred to as “multiple risk behaviour”⁶ and “Problem Behaviour Theory”.⁷ Further, although relationships between risk behaviours assessed individually and the occurrence of injury are well known and studied, there is less empirical research on relationships between risk behaviours measured in clusters and the occurrence of adolescent injury.¹ Early evidence of associations between groups of risk behaviour and injury are compelling, and these provided a motivation for our current study.^{6,8}

Studies of adolescent risk-taking have most commonly focused on a small set of indicators (i.e. smoking cigarettes, getting drunk, and unprotected sex).¹ However, this list represents only a fraction of the possibilities. Indeed, more than 20 years ago the US Centers for Disease Control and Prevention (CDC) proposed a standard framework for known risky behaviours at the time that were potentially harmful to adolescent health.⁹ This framework classified risk behaviours into domains thought to be associated with leading causes of adolescent illness and injury.⁹ In a recent national study, we explored this framework in detail and tested empirically how clusters of risk behaviours from multiple domains represent different manifestations of adolescent risk behaviour in contemporary, real-world settings.⁵ However, instead of the six domains suggested by the CDC framework, we observed three clusters of risk behaviours: 1) *Overt Risk Taking* (i.e., smoking, drinking alcohol, energy drink consumption, and bullying), 2) *Active Healthy Lifestyle Detriment* (i.e., sedentary behaviours and potato chip/soda consumption), and 3) *Passive Healthy Lifestyle Detriment* (i.e., physical inactivity and low fruit/vegetable intake) (**Online Supplemental Table A**).⁵ Via different mechanisms, each of these clusters is potentially associated with illness and injury.

Adolescent injuries are common in Canada and their occurrence can result in substantial disability and economic loss.¹⁰ Schools represent settings that are frequently associated with injury¹⁰, despite the protective nature of these environments when they have the capacity to nurture student growth both socially and physically.¹¹ Many programs exist that focus on the social climates of schools and associated student populations as a means to address adolescent risk-taking.¹² There is mixed evidence, however, about the effectiveness of such programs in preventing injury.^{12,13} One possible explanation is that most existing interventions have approached the study of injury and its potential causes, both behavioural and contextual without the use of a theoretical framework to guide their etiological thinking. Population health theory suggests that individual student factors (e.g., risk-taking behaviour) and environmental factors (e.g., school social climate) may interact together to produce varying risks for injury in adolescents,¹⁴ and this theory provides an excellent basis for study of the etiology of school injury. The current study therefore extends our work by applying population health theory to the study of our refined measures of adolescent risk-taking and the occurrence of adolescent injury in Canada. We had a unique opportunity to perform such a study on a national basis using contemporary health survey data. Our objectives were to study if risk behaviours measured in groups or clusters are indeed associated with the occurrence of school injuries, and whether such relationships are modified by the presence or absence of protective school environments.

4.3 Methods

Study Base and Sampling

Our study base was an interim dataset from the 2014 Canadian Health Behaviour in School-aged Children (HBSC) study,¹⁰ which evaluated health outcomes, attitudes, and behaviours of 17,428 students (unweighted) from 227 schools across Canada. Students aged 11-15 years were sampled using a multi-level cluster sampling approach. The study base was the public and separate school systems in all Canadian territories and provinces, representing approximately 93% of the Canadian population of

children aged 11-15 years in Canada.¹⁰ Exclusions were students enrolled in private, special needs, on-reserve, or religious based schools as well as home schools and incarcerated children. Following provincial and then school board approval, schools and then classrooms within schools were selected for study within groups defined by: geographical location (provincial region), language of instruction, religion, and community size. Eligible and consenting students within selected classes were then given a confidential questionnaire to complete in a single classroom period. Younger students in Grades 6-8 were given an abbreviated questionnaire with measures of sensitive-nature omitted (i.e., items describing sexual behaviours and illicit drug use).

Multiple Risk Behaviour Categories

Exploratory factor analysis was used to measure relationships between risk behaviours spanning multiple CDC risk behaviour domains to develop the three categories used in this study. Our empirical assessment of the CDC framework, including a subsequent confirmatory factor analysis to validate our findings, supported a three-category approach to represent the different manifestations of adolescent risk behaviour. Factor loadings below 0.30 were suppressed. Across grade ranges, the resulting factor loadings (FL) ranged from 0.30-0.84, and measures of internal consistency (i.e. Cronbach's α) ranged from 0.71-0.88 across all three common factors, *Overt Risk Taking* (Grades 6-8: FL = 0.30-0.71; α = 0.74; Grades 9-10: FL = 0.34-0.84; α = 0.88), *Active Healthy Lifestyle Detriment* (Grades 6-8: FL = 0.30-0.70; α = 0.72; Grades 9-10: FL = 0.54-0.74; α = 0.77), and *Passive Healthy Lifestyle Detriment* (Grades 6-8: FL = 0.46-0.66; α = 0.72; Grades 9-10: FL = 0.48-0.71; α = 0.71).

Aggregate scores for each multiple risk behaviour category were calculated for all students using statistical weights generated through the exploratory factor analysis. Scores from each risk behaviour category were then split into three groups (commonly tertiles) to classify students as low, moderate, or high risk relative to other students. Due to differences in available risk behaviours from the HBSC study, this process was performed separately for students in two separate grade groups (Grades 6-8, 9-10). Further details about the development of the risk behaviour categories, as well as the associated weighting

of factors into associated composite measures can be found in the companion study (Chapter 3 in this thesis).⁵

School Injuries

Injury outcomes were identified using a combination of questions from the HBSC survey eliciting information about the number, location, and severity of the injury, as well as the activity and circumstances that led to the injury event. Students were asked to report injuries requiring care from a doctor or a nurse. These questions and possible responses were developed based on current surveillance programs and injury classification protocols,¹⁵ and have been assessed for validity using hospital records.¹⁶ Questions about injury from the HBSC have also been used in numerous national and international studies (e.g., Pickett et al¹⁷ and Freeman et al¹⁰). Using the modified abbreviated injury score developed for this survey,¹⁸ severe injuries were defined as ones requiring a cast, stitches, or an overnight stay in hospital.

School Climate

A School Climate Scale was refined and validated for use in this study using a split-sampling method. Questions pertaining to self-perceived school capacity (i.e., “When I need extra help, I can get it”), teacher support¹⁹ (i.e., “Our teachers treat us fairly”), and student support¹⁹ (i.e., “Other students accept me as I am”) were extracted from the HBSC questionnaire and analyzed using exploratory factor analysis to develop a composite measure of school climate. We used maximum likelihood extraction with promax rotation, and this method indicated a three-factor solution. Factor loadings below 0.30 were suppressed and ranged from 0.44-0.84 in the final model (Grade 6-8 RMSEA = 0.073; Grade 9-10 RMSEA = 0.077). We used the first factor consisting of 12 items that incorporated aspects of teacher support and school capacity to represent our School Climate Scale (Cronbach’s alpha values were 0.92 for Grade 6-8 students and 0.91 for Grade 9-10 students). Confirmatory factor analysis was also performed on a separate sub-set of students to evaluate the validity of the factor structure derived from the exploratory factor analysis (Grade 6-8 RMSEA = 0.073; Grade 9-10 RMSEA = 0.075).

Measures of overall school climate were calculated by averaging all student responses within the same school. First, aggregate scores of perceived school climate were calculated for each student using statistical weights (factor loadings) created during the exploratory factor analysis. Students with 30% or fewer missing responses to the measures in the School Climate Scale had their missing responses imputed using mean scores to improve sample size and associated statistical power. Scores were then averaged across each school to develop an estimate of overall student-perceived climate for their school. School climate scores were split into tertiles and each student was designated as being in a low, medium or high climate school. This process was performed separately for the two grade groups (Grades 6-8, 9-10) as existing literature suggests that students perceive school climate differently as they get older.¹¹

Confounders

The following confounders were considered in the analysis: biological sex (boy vs. girl),²⁰ grade level (5 to 11),²¹ socioeconomic status (SES),²² student learning exceptionalities,²³ living or working on a farm,²⁴ ethnicity ('White', 'Metis, Inuit, and First Nations', 'East and Southeast Asian', 'Black', 'Latin American and Other', 'South Asian', 'Arab and West Asian'),²⁵ and the number of years lived in Canada ('Born in Canada', '1-2 years', '3-5 years', '6-10 years', '11 or more years').²⁶ SES was measured using the validated HBSC Family Affluence Scale that considers the number of cars and computers that a family owns, whether the student has their own room, and the frequency of family vacations.²⁷ Consideration of these variables as potential confounders was based on existing literature and conceptual theory. Possible confounders were also limited to the availability of demographic characteristics in the HBSC survey.

Statistical Analyses

We first described the study population by basic demographic characteristics. Regression analyses were then performed, with both performed separately for the two grade groups (Grades 6-8, 9-10). Given the clustered nature of the HBSC sampling procedure, a variance partitioning analysis was conducted to assess the need for a multi-level regression analysis. Intra-class correlation (ICC) values for Grade 6-8 students (ICC = 0.005) and Grade 9-10 (ICC = 0.012) at the school-level show that a negligible proportion

of variation was attributed to schools. Therefore, basic regression analyses for dichotomous outcomes were used in this study.

We first evaluated the relationship between the three categories of risk behaviours and the occurrence of school injuries using a multiple logistic regression to generate odds ratio estimates, which due to the rare levels of injury outcomes estimated relative risk. General school injuries, as well as specific sub-types of school injury (e.g., injuries caused by running, sports, or fighting) were assessed in different models. A backwards elimination modeling strategy and change in estimate approach was used to evaluate potential confounders.²⁸ Based on existing literature suggesting strong relationships with both risk behaviour and injury, biological sex and SES were forced into all models. For the second analysis, we tested the Population Health Framework by assessing school climate as an effect modifier of the relationship between risk behaviour and school injury. Multiplicative interaction terms were used to assess this effect modification. All regression analyses were evaluated for model goodness of fit using Hosmer-Lemeshow tests, residual plots, and Q-Q plots. All analyses in this study were conducted in SAS (Version 9.4, SAS Institute, Cary, NC).

4.4 Results

Sample Population

The 2014 interim dataset from the Canadian HBSC Study had responses from 9,643 Grade 6-8 students and 7,785 Grade 9-10 students from 227 schools across Canada. A demographic description of the study population is provided in **Table 1**.

Multiple Risk Behaviour Categories and School Injury

Relationships between the three risk behaviour scales and the occurrence of school injury appeared to differ between grade groups. Although participation in risk behaviour (from any category) was not related to school injury among students in Grades 9-10, there were mixed results in the younger grades (Grades 6-8) (**Tables 2 and 3**). High-risk Grade 6-8 students were more likely to be injured at

school than their low-risk peers from the *Overt Risk Taking* (OR = 1.61, 95% CI = 1.30, 2.01) and *Active Healthy Lifestyle Detriment* (OR = 1.24, 95% CI = 0.99, 1.55) behaviour categories. A possible dose response was observed for both of these categories showing increased odds of injury as participation in these risk behaviours increased. There was no clear relationship, however, observed between the level of participation in *Passive Healthy Lifestyle Detriment* behaviours and school injury.

Grade 6-8 students participating in *Overt Risk Taking* Behaviours were also at greater risk for several specific sub-types of school injury that were evaluated. High-risk students in this category were more likely to be seriously injured at school, injured during school hours, or injured as a result of a fight. High-risk Grade 6-8 students in all three risk categories were at a greater likelihood of getting injured because of a fight. Grade 9-10 students showed inconsistent dose-response relationships between levels of risk in each risk behaviour category and sub-type of school injury, further supporting a lack of association between risk behaviour and injury in this grade group.

School Climate as a Contextual Effect Modifier

School climate was evaluated as an effect modifier by evaluating the statistical significance of two-way interaction terms between school climate item by each indicator of risk behaviour on the relative odds of school injury. In almost all cases, school climate was not found to significantly modify the relationship between risk behaviours and school injury. The influence of school climate on these relationships was also inconsistent in terms of direction and sizes of observed effects. Therefore, school climate does not appear to be an effect modifier of relationships between risk behaviours and school injury.

Though age was not initially evaluated as an effect modifier, our stratified analyses showed different gradients of association across levels of school climate in both grade groups, suggesting grade or age to be an effect modifier. **Tables 4 and 5** show that school climate changed both the direction and magnitude of relationships between risk behaviour and injury across the two grade groups. For example, among Grade 6-8 students, the relative odds of sustaining an injury in association with *Overt Risk Taking*

behaviours appeared to increase as school climate improved. However, the opposite trend was seen in Grade 9-10 students participating in the same types of risk behaviours. Therefore, given the inconsistent contextual contributions of school climate, as well as its age-specific influence on gradients of association between risk behaviour and injury, school climate appears to play a complex and context-specific role that does not result in consistent effects.

4.5 Discussion

This study explored the etiology of school injury using existing population health theory that stresses the importance of both direct and interactive effects between risk behaviours and school climate.¹⁴ We used new scales describing three forms of adolescent risk behaviour that represent a refined version of the CDC risk behaviour framework.⁵ Our study found that risk behaviours from two different domains (*Overt Risk Taking* and *Active Healthy Lifestyle Detriment*) were associated with the odds of school injury reported by younger students. We also found that school climate influenced the relationship between risk behaviour and a school injury in highly variable and inconsistent manners, suggesting that it is not an effect modifier. The effect of school climate on this relationship may depend on the age of students under study, and the context in which injuries actually occur.

Risk behaviours are important potential determinants of injury among younger students (Grades 6-8). Engagement in such behaviours at this age may represent more extreme types of risk-taking that are unusual for students developmentally. *Overt Risk Taking* behaviours emerged as particular concerns because of their association with general school injuries, as well as several sub-types of school injury. Previous studies have found that these types of behaviours are uncommon during early adolescence,¹⁰ may be associated with problematic early psychosocial development,²⁹ and may often result in poor educational and lifestyle outcomes as children age and develop.³⁰ Young, high-risk students in this category may have an exceptionally high level of comfort with behaviours that they know are not considered normative among their peers. This high level of comfort with risk behaviour may be related to a heightened

acceptance of ambiguity or apathy towards accepted social norms that may put them at greater risk for injury at school.³¹ Conversely, high-risk students from the *Passive Healthy Lifestyle Detriment* category may not perceive normative behaviours in such a discordant manner, which may explain the absence of its relationship with injury.

School climate appears to have a complex and variable influence on relationships between risk behaviour and injury. We did identify some gradients in the odds of injury between levels of risk behaviour that varied across different levels of school climate. However, gradients in the relative odds of injury were modified both in terms of direction and magnitude depending on the age of the students, as well as the type of school injury that was being assessed. This inconsistency suggests that school climate is not an effect modifier, but that its influence on these relationships may be much more complex. For example, positive school climate appeared to play a strong potential role in preventing school injury associated with *Overt Risk Behaviours* among older students (Grades 9-10). High-risk students in schools with the highest levels of school climate were less likely to get hurt at school than the same students in schools with poor school climate, relative to their low-risk peers. However, the opposite gradient was observed among younger students (Grades 6-8) in the same risk category. For younger students, it appears that high school climate facilitates a greater likelihood of injury, however there was a lack of consistency in observed effects. The lack of consistency observed across age groups and different injury outcomes suggests that school climate influences these relationships in varied and context-specific ways, and the basic tenets of population health theory, that individual and contextual factors interact to produce varying states of injury risk, therefore does not always hold.

The inconsistent potential effects of school climate on the occurrence of injury observed in this study may have occurred for two reasons. First, the influence of social supports in school may be different based on the types of injury, the context in which they arise, and the age levels of the students. Previous studies suggest that students perceive and value school climate differently as they grow up.¹¹ School climates may also present in a variety of ways during different activities (i.e., authoritative structure

within organized sports, or more free during free time and recess), which may alter the influence of school climates on the relationships between risk behaviour and injury. Second, although school climates have been shown to reduce conventional risk behaviours in school (i.e., smoking cigarettes and fighting),³² they may not be able to ameliorate the risky attitudes and behaviours of students in a way that reduces their chances of sustaining an injury at school. Participation in the specific behaviours associated with the risk behaviour categories may only be an indication of a general form of risky attitudes and behaviours in the classroom or the playground that lead to injuries at school, which may not be addressed by school climate.

Our findings have implications for additional research and prevention. Improving school climate may not be enough to prevent school injuries stemming from an adolescent's level of risk-tolerance. We believe that research and interventions should focus on two areas. First, future research should investigate risk factors associated with the risk categories used in this study. Intervention programs targeting risk factors may prevent the development of these risk behaviours and may also be able to address associated attitudes and beliefs that lead to injuries at school. Second, studies should continue to assess other potential contextual influences and intervention programs capable of addressing the cluster of behaviours currently exhibited among high-risk students. Doing so may ameliorate the risk that these behaviours have on associated downstream health consequences.

A limitation of this study is its use of self-reported data, which may have led to social desirability biases. Confidentiality was emphasized to students at various stages of the study administration in an attempt to minimize this form of potential bias. Although school climate is a universal concept that affects all students within the school, student experiences with social connectedness within a particular school may differ. It is possible that aggregating student experiences into a school-level measure of school climate may have left variable experiences of student connectedness within a school unrepresented. School injuries were based on student reports of their "single most serious injury". Therefore, minor school injuries or multiple occurrences of injury from the same student were not captured by the survey and may have limited our statistical power to observe associations in our analyses. It is possible that

students may also have forgotten about some injury events. However, a previous study showed that students have a good memory of injuries within a 12-month period, especially if the injuries are serious.³³ Multiple comparisons may also be a limitation of this study based on the 241 statistical tests performed. Based on a type-I error rate of 0.05, we expect 12 significant associations by chance. Therefore, statistical significance of our results should be interpreted with caution. Lastly, this study was performed on an interim Cycle 7 HBSC dataset and had lower representation from British Columbia and the three Northern Territories of Canada. Statistical weights were also unavailable at the time of analysis. Proportional estimates are not representative of the entire Canadian population in this age group.

4.6 Conclusion

We used a large sample of Canadian adolescents to evaluate injury risk based on adolescent participation in three contemporary conceptualizations of risk behaviour.⁵ Our study was able to confirm previous research showing a relationship between two forms of risk behaviour (*Overt Risk Taking* and *Active Healthy Lifestyle Aversion*) and injury risk. We also performed an analysis, grounded in population health theory,¹⁴ to evaluate the contextual influence of school climate on the relationship between risk behaviour and injury risk. Observed gradients of influence were found based on changes in school climate. However, the effect of school climate was inconsistent and could not be generalized based on student age or specific sub-types of school injury. Given the numerous interventions targeted towards the improvement of school climate,³² we recommend additional research into the etiological pathways supporting these interventions before further implementation. Future research should also address upstream determinants (risk factors) of risk behaviour categories to prevent the development of constructs of risk-tolerance that have established consequences on injury.

4.7 Key Points

What is already known on this subject?

- Individual risk behaviours are related to school injury and are currently targeted in intervention programs by improving school climate. These programs have had mixed success.
- Prior research shows that adolescent risk behaviours are related and should be evaluated and addressed collectively.

What does this study add?

- Risk behaviour clusters were also found to be associated with school injuries. Young, overt risk-takers were identified as a specific high-risk group for injury.
- School climate has a complex and inconsistent influence on the relationship between risk behaviour and school injury that is not easily generalizable across different grade groups or types of school injury.

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Author's Contributions

All authors had significant input on the study conceptualization and design. WP provided access to all data used in this study. All statistical analyses were performed by JK. All authors were involved in the interpretation of statistical results, as well as the drafting and revision of the manuscript.

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Competing Interests

None declared.

Provenance and Peer Review

Not commissioned; externally peer-reviewed.

Data Sharing Statement

Data for this study came from the 2014 Canadian Health Behaviour in School-aged Children (HBSC) Study. Authors will share information about data collection upon request.

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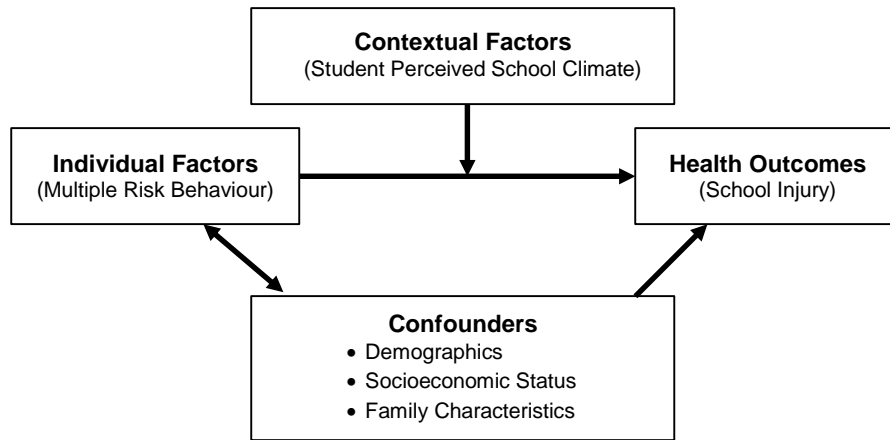


Figure 1. Conceptual Model based on Population Health Framework. This study evaluated dual-levels of possible determinants of school injury by considering multiple risk behaviour (an individual factor), and school climate (a contextual factor). School climate was assessed as a potential contextual effect modifier and a possible point of future injury prevention intervention.

Table 1. 2013-2014 HBSC study population demographic characteristics.

Adolescent Characteristic	<i>n</i>	%
Gender		
Male	8 566	50.6
Female	8 779	49.4
Missing	83	
Family Affluence		
Low	575	3.6
Medium	5 610	35.2
High	9 767	61.2
Missing	1 476	
School Injuries		
Playing or Training for Sport	676	55.9
Walking or Running	173	14.3
Fighting	56	4.6
Bicycling or Cycling	32	2.7
Riding/Driving a Car or Motor Vehicle	9	0.7
Working	5	0.4
Other	258	21.3
Missing	968	
Ethnicity		
White	13 111	76.6
Metis, Inuit, and First Nations	1838	10.7
East and Southeast Asian	734	4.3
Black	546	3.2
Latin American and Other	396	2.3
South Asian	327	1.9
Arab and West Asian	173	1.0
Missing	303	
Years Lived in Canada		
Born in Canada	14 236	83.0
1 to 2 Years	325	1.9
3 to 5 Years	378	2.2
6 to 10 Years	210	3.0
11 or More Years	1 701	9.9
Missing	268	
Farm Status		
Living or Working on a Farm	1 388	8.1
Not Living or Working on a Farm	15 759	91.9
Missing	281	
Learning Exceptionality or Special Education Need		
Not Diagnosed	10 677	81.8
Behaviour and ADHD	823	6.3
Physical Disability and Speech Impairment	412	3.2
Learning Disability	419	3.2
Gifted	297	2.3
Autism/Asperger Syndrome and Intellectual Disability	162	1.2
Other	265	2.0
Missing	4373	

Table 2. Odds ratio estimates describing the association between risk behaviour categories and school injury outcomes in Grade 9-10 students.

Outcome: Risk Category	Factor 1		Factor 2		Factor 3	
	Overt Risk Taking		Active Healthy Lifestyle Detriment		Passive Healthy Lifestyle Detriment	
	OR*	95% CI	OR*	95% CI	OR*	95% CI
School Injuries						
High Risk	1.13	(0.87, 1.47)	1.28	(0.97, 1.67)	0.99	(0.76, 1.28)
Medium Risk	1.19	(0.92, 1.54)	1.22	(0.94, 1.59)	0.91	(0.70, 1.18)
Low Risk	1.00		1.00		1.00	
Serious Injuries						
High Risk	1.13	(0.75, 1.70)	1.29	(0.84, 1.98)	0.93	(0.62, 1.39)
Medium Risk	1.05	(0.69, 1.58)	1.27	(0.83, 1.94)	0.82	(0.54, 1.24)
Low Risk	1.00		1.00		1.00	
Injuries: During School Hours						
High Risk	0.93	(0.68, 1.29)	1.35	(0.97, 1.88)	0.99	(0.72, 1.36)
Medium Risk	1.16	(0.85, 1.60)	1.31	(0.95, 1.81)	0.98	(0.71, 1.34)
Low Risk	1.00		1.00		1.00	
Injuries: After School Hours						
High Risk	1.58	(1.02, 2.43)	1.13	(0.73, 1.75)	0.98	(0.65, 1.49)
Medium Risk	1.24	(0.79, 1.95)	1.05	(0.68, 1.63)	0.80	(0.51, 1.23)
Low Risk	1.00		1.00		1.00	
Sports Injuries						
High Risk	0.93	(0.67, 1.29)	1.09	(0.77, 1.52)	0.78	(0.57, 1.08)
Medium Risk	1.08	(0.79, 1.47)	1.21	(0.88, 1.68)	0.79	(0.58, 1.09)
Low Risk	1.00		1.00		1.00	
Walking or Running Injuries						
High Risk	0.73	(0.30, 1.78)	1.43	(0.60, 3.42)	1.38	(0.61, 3.15)
Medium Risk	1.45	(0.68, 3.07)	1.56	(0.68, 3.58)	1.23	(0.53, 2.85)
Low Risk	1.00		1.00		1.00	
Fighting Injuries						
High Risk	6.29	(0.76, 52.38)	1.72	(0.43, 7.00)	2.62	(0.52, 13.14)
Medium Risk	4.05	(0.45, 36.31)	0.57	(0.10, 3.43)	1.37	(0.23, 8.26)
Low Risk	1.00		1.00		1.00	
Other Injuries of Unknown Cause						
High Risk	1.68	(0.92, 3.05)	1.70	(0.91, 3.20)	1.65	(0.90, 3.03)
Medium Risk	1.20	(0.63, 2.23)	1.41	(0.75, 2.67)	1.11	(0.58, 2.16)
Low Risk	1.00		1.00		1.00	

*Logistic regression adjusted for sex and family affluence. Odds ratios are relative to low-risk as the reference group. Biking, motor vehicle, and work injuries were not able to be assessed due to an insufficient number of cases.

Table 3. Odds ratio estimates describing the association between risk behaviour categories and school injury outcomes in Grade 6-8 students.

Outcome: Risk Category	Factor 1 Overt Risk Taking		Factor 2 Active Healthy Lifestyle Detriment		Factor 3 Passive Healthy Lifestyle Detriment	
	OR*	95% CI	OR*	95% CI	OR*	95% CI
	School Injuries					
High Risk	1.61	(1.30, 2.01)	1.24	(0.99, 1.55)	0.99	(0.79, 1.23)
Medium Risk	1.38	(1.10, 1.73)	1.20	(0.96, 1.51)	1.00	(0.80, 1.26)
Low Risk	1.00		1.00		1.00	
Serious Injuries						
High Risk	1.87	(1.32, 2.64)	1.00	(0.69, 1.44)	0.75	(0.52, 1.06)
Medium Risk	1.23	(0.84, 1.80)	1.27	(0.90, 1.80)	0.86	(0.61, 1.23)
Low Risk	1.00		1.00		1.00	
Injuries: During School Hours						
High Risk	1.64	(1.29, 2.10)	1.26	(0.99, 1.61)	1.05	(0.82, 1.34)
Medium Risk	1.39	(1.08, 1.80)	1.11	(0.86, 1.42)	1.00	(0.77, 1.29)
Low Risk	1.00		1.00		1.00	
Injuries: After School Hours						
High Risk	1.42	(0.88, 2.28)	1.10	(0.66, 1.85)	0.76	(0.47, 1.25)
Medium Risk	1.28	(0.78, 2.09)	1.58	(0.98, 2.54)	1.01	(0.63, 1.62)
Low Risk	1.00		1.00		1.00	
Biking/Cycling Injuries						
High Risk	1.85	(0.60, 5.70)	1.76	(0.53, 5.91)	1.78	(0.52, 6.05)
Medium Risk	0.52	(0.10, 2.71)	0.97	(0.24, 3.92)	1.10	(0.27, 4.40)
Low Risk	1.00		1.00		1.00	
Sports Injuries						
High Risk	1.22	(0.90, 1.67)	0.99	(0.71, 1.38)	0.79	(0.57, 1.10)
Medium Risk	1.24	(0.91, 1.71)	1.29	(0.94, 1.76)	1.24	(0.91, 1.69)
Low Risk	1.00		1.00		1.00	
Walking or Running Injuries						
High Risk	1.01	(0.60, 1.69)	1.17	(0.69, 1.97)	1.10	(0.67, 1.83)
Medium Risk	0.98	(0.58, 1.66)	1.13	(0.67, 1.92)	0.81	(0.47, 1.42)
Low Risk	1.00		1.00		1.00	
Fighting Injuries						
High Risk	27.89	(3.72, 209.20)	2.82	(1.02, 7.82)	4.62	(1.33, 16.10)
Medium Risk	4.41	(0.46, 42.60)	1.01	(0.29, 3.50)	2.46	(0.64, 9.56)
Low Risk	1.00		1.00		1.00	
Other Injuries of Unknown Cause						
High Risk	2.05	(1.29, 3.25)	1.53	(0.97, 2.40)	1.13	(0.74, 1.74)
Medium Risk	2.01	(1.26, 3.21)	1.21	(0.77, 1.95)	0.76	(0.47, 1.25)
Low Risk	1.00		1.00		1.00	

*Logistic regression adjusted for sex and family affluence. Odds ratios are relative to low-risk as the reference group. Vehicle and work injuries were not able to be assessed due to an insufficient number of cases.

Table 4. Relationships between level of risk in each risk category and school injury outcomes, stratified by level of school climate among Grade 9-10 students.

Outcome: School Climate Category	Low Risk OR*	Medium Risk OR* 95% CI	High Risk OR* 95% CI	Interaction P-Value
Risk Scale 1: Overt Risk Taking				
School Injuries (N = 555)				
High School Support	1.00	0.86 (0.58, 1.27)	1.08 (0.73, 1.60)	P = 0.48
Medium School Support	1.00	1.35 (0.92, 1.98)	1.25 (0.85, 1.84)	
Low School Support	1.00	1.32 (0.88, 1.97)	1.36 (0.92, 2.01)	
Serious Injuries (N = 214)				
High School Support	1.00	0.57 (0.30, 1.10)	0.96 (0.53, 1.73)	P = 0.44
Medium School Support	1.00	1.29 (0.68, 2.45)	1.50 (0.81, 2.79)	
Low School Support	1.00	1.21 (0.66, 2.23)	1.32 (0.73, 2.38)	
Sports Injuries (N = 347)				
High School Support	1.00	1.11 (0.70, 1.75)	1.18 (0.73, 1.89)	P = 0.96
Medium School Support	1.00	1.02 (0.65, 1.60)	0.96 (0.61, 1.52)	
Low School Support	1.00	1.20 (0.73, 2.00)	1.01 (0.61, 1.69)	
Risk Scale 2: Active Healthy Lifestyle Detriment				
School Injuries (N = 555)				
High School Support	1.00	1.30 (0.86, 1.97)	1.49 (0.99, 2.24)	P = 0.50
Medium School Support	1.00	1.11 (0.75, 1.63)	1.29 (0.88, 1.90)	
Low School Support	1.00	0.90 (0.62, 1.31)	0.92 (0.62, 1.35)	
Serious Injuries (N = 214)				
High School Support	1.00	2.11 (1.03, 4.34)	2.24 (1.10, 4.60)	P = 0.10
Medium School Support	1.00	0.73 (0.40, 1.33)	0.76 (0.41, 1.39)	
Low School Support	1.00	0.91 (0.51, 1.63)	1.02 (0.57, 1.83)	
Sports Injuries (N = 347)				
High School Support	1.00	1.08 (0.67, 1.74)	1.12 (0.69, 1.80)	P = 0.93
Medium School Support	1.00	0.94 (0.60, 1.48)	1.02 (0.64, 1.61)	
Low School Support	1.00	1.16 (0.71, 1.90)	0.96 (0.56, 1.63)	
Risk Scale 3: Passive Healthy Lifestyle Detriment				
School Injuries (N = 555)				
High School Support	1.00	1.53 (1.02, 2.30)	1.41 (0.93, 2.13)	P = 0.07
Medium School Support	1.00	0.72 (0.50, 1.04)	0.80 (0.55, 1.16)	
Low School Support	1.00	0.83 (0.56, 1.24)	1.05 (0.72, 1.52)	
Serious Injuries (N = 214)				
High School Support	1.00	1.20 (0.61, 2.36)	1.77 (0.94, 3.34)	P = 0.02
Medium School Support	1.00	0.46 (0.25, 0.84)	0.46 (0.25, 0.85)	
Low School Support	1.00	1.14 (0.61, 2.10)	1.34 (0.74, 2.41)	
Sports Injuries (N = 347)				
High School Support	1.00	1.04 (0.65, 1.69)	1.21 (0.76, 1.94)	P = 0.44
Medium School Support	1.00	0.64 (0.41, 0.99)	0.66 (0.42, 1.04)	
Low School Support	1.00	0.94 (0.57, 1.55)	0.83 (0.50, 1.38)	

*Logistic regression adjusted for sex and family affluence. Odds ratios are relative to low-risk as the reference group. Running/walking injuries were not able to be assessed due to an insufficient number of cases.

Table 5. Relationships between level of risk in each risk category and school injury outcomes, stratified by level of school climate among Grade 6-8 students.

Outcome: School Climate Category	Low Risk OR*	Medium Risk OR* 95% CI	High Risk OR* 95% CI	Interaction P-value
Risk Scale 1: Overt Risk Taking				
School Injuries (N = 717)				
High School Support	1.00	1.60 (1.16, 2.21)	1.96 (1.41, 2.72)	P = 0.71
Medium School Support	1.00	1.46 (1.00, 2.13)	1.62 (1.14, 2.32)	
Low School Support	1.00	1.23 (0.88, 1.74)	1.43 (1.04, 1.96)	
Serious Injuries (N = 278)				
High School Support	1.00	2.23 (1.37, 3.63)	2.46 (1.48, 4.08)	P = 0.34
Medium School Support	1.00	1.20 (0.64, 2.24)	1.87 (1.09, 3.22)	
Low School Support	1.00	1.00 (0.54, 1.86)	1.78 (1.05, 2.99)	
Sports Injuries (N = 329)				
High School Support	1.00	1.52 (0.99, 2.32)	1.53 (0.97, 2.41)	P = 0.69
Medium School Support	1.00	1.69 (0.96, 2.98)	1.52 (0.87, 2.67)	
Low School Support	1.00	1.04 (0.64, 1.67)	1.02 (0.65, 1.61)	
Walking/Running Injuries (N = 108)				
High School Support	1.00	1.24 (0.59, 2.61)	0.94 (0.38, 2.31)	P = 0.89
Medium School Support	1.00	0.92 (0.42, 2.00)	0.92 (0.44, 1.92)	
Low School Support	1.00	0.79 (0.33, 1.90)	1.11 (0.52, 2.38)	
Risk Scale 2: Active Healthy Lifestyle Detriment				
School Injuries (N = 717)				
High School Support	1.00	1.15 (0.84, 1.59)	1.23 (0.89, 1.70)	P = 0.83
Medium School Support	1.00	1.26 (0.88, 1.80)	1.07 (0.74, 1.55)	
Low School Support	1.00	1.20 (0.85, 1.67)	1.27 (0.92, 1.76)	
Serious Injuries (N = 278)				
High School Support	1.00	1.08 (0.67, 1.72)	0.98 (0.60, 1.60)	P = 0.82
Medium School Support	1.00	1.28 (0.73, 2.23)	1.03 (0.57, 1.85)	
Low School Support	1.00	0.96 (0.55, 1.69)	1.17 (0.69, 1.97)	
Sports Injuries (N = 329)				
High School Support	1.00	1.36 (0.88, 2.10)	1.30 (0.83, 2.03)	P = 0.47
Medium School Support	1.00	1.25 (0.74, 2.11)	0.70 (0.38, 1.29)	
Low School Support	1.00	1.24 (0.78, 1.98)	1.00 (0.62, 1.61)	
Walking/Running Injuries (N = 108)				
High School Support	1.00	1.56 (0.73, 3.37)	1.14 (0.49, 2.67)	P = 0.77
Medium School Support	1.00	0.78 (0.37, 1.64)	0.71 (0.33, 1.52)	
Low School Support	1.00	1.32 (0.58, 3.03)	1.17 (0.51, 2.70)	
Risk Scale 3: Passive Healthy Lifestyle Detriment				
School Injuries (N = 717)				
High School Support	1.00	0.95 (0.69, 1.30)	0.90 (0.65, 1.24)	P = 0.18
Medium School Support	1.00	0.68 (0.47, 0.99)	0.65 (0.45, 0.92)	
Low School Support	1.00	1.17 (0.83, 1.66)	1.15 (0.82, 1.60)	
Serious Injuries (N = 278)				
High School Support	1.00	1.02 (0.65, 1.59)	0.64 (0.38, 1.08)	P = 0.24
Medium School Support	1.00	0.58 (0.33, 1.03)	0.51 (0.29, 0.90)	
Low School Support	1.00	0.88 (0.50, 1.56)	0.94 (0.55, 1.59)	
Sports Injuries (N = 329)				
High School Support	1.00	1.14 (0.76, 1.72)	0.79 (0.50, 1.26)	P = 0.24
Medium School Support	1.00	0.63 (0.36, 1.11)	0.61 (0.36, 1.06)	
Low School Support	1.00	1.38 (0.87, 2.18)	0.67 (0.41, 1.11)	
Walking/Running Injuries (N = 108)				
High School Support	1.00	0.74 (0.34, 1.61)	0.71 (0.32, 1.57)	P = 0.27

Medium School Support	1.00	0.72 (0.33, 1.56)	0.78 (0.38, 1.62)
Low School Support	1.00	1.92 (0.67, 5.57)	2.75 (1.02, 7.40)

*Logistic regression adjusted for sex and family affluence. Odds ratios are relative to low-risk as the reference group.

Online Supplemental Table A. Risk behaviours associated with each category and the associated cut-offs used to designate level of student participation as none/minimal, moderate, or frequent.

Risk Behaviours	None/Minimal	Moderate	Frequent
Risk Behaviour Category 1: Overt Risk-Taking			
Smoking Behaviour			
Number of days they smoked cigarettes in their life	Never	1-29 Days	30 Days+
Alternative tobacco products (e.g., e-cigarette, flavoured tobacco...) [†]	Never used any	Used one once or more	Used several once or more
Alcohol and Illicit Substance Use			
Frequency of alcohol consumption (e.g., beer, wine, cider...) [†]	Never drank any	Rarely	Every month - Every day
Number of drinks per typical event	Never drank	Less than one - One drink	2 Drinks+
Number of times they got drunk in their life*	Never	Once	2 Times+
Frequency of binge drinking in the last year*	Never drank - Never binged	Less than or once a month	2-3 times a month - Daily
Number of days they used cannabis in their life*	Never	1-5 Days	6 Days+
Number of times they used hard drugs (e.g., ecstasy, solvents, pain medication...) [†]	Never used any	Used one once	Used several once or more
High-Risk Sexual Behaviours			
Lifetime sexual history and use of contraceptives ^{††}	Never had sex	Had sex using contraception	Sex without contraception
High-Risk Manifest Behaviours			
Number of times they got into a fight in the last year	No fights	Once	2 Times+
Frequency of personal bullying behaviours on others [‡]	No bullying	Once - 3 times a month	Once a week or more
Unhealthy Dietary Pattern			
Frequency of energy drink consumption in a typical week	Never	Less than or once a week	2-4 times a week or more
Risk Behaviour Category 2: Active Healthy Lifestyle Detriment			
Unhealthy Dietary Pattern			
Frequency of pop/soda consumption in a typical week [‡]	Never - Once a week	2-4 times a week	5-6 times a week or more
Frequency of chip consumption in a typical week [‡]	Never - Once a week	2-4 times a week	5-6 times a week or more
Physical Inactivity			
Hours watching TV or videos on a typical weekday	None - One hour	2-3 Hours	4+ Hours
Hours watching TV or videos on a typical weekend	None - One hour	2-3 Hours	4+ Hours
Hours playing video games on a typical weekday	None - One hour	2-3 Hours	4+ Hours
Hours playing video games on a typical weekend	None - One hour	2-3 Hours	4+ Hours
Risk Behaviour Category 3: Passive Healthy Lifestyle Detriment			
Unhealthy Dietary Pattern			
Frequency of fruit consumption in a typical week	Once or more a day	2-6 times a week	Never - Once a week
Frequency of vegetable consumption in a typical week	Once or more a day	2-6 times a week	Never - Once a week
Frequency of orange vegetable consumption in a typical week	Once or more a day	2-6 times a week	Never - Once a week
Physical Inactivity			
Number of days physically active for 60+ min. last week	6-7 Days	3-5 Days	0-2 Days
Number of days physically active for 60+ min. in a typical week	6-7 Days	3-5 Days	0-2 Days

Note: Coding within each level of risk may represent an aggregate of multiple questionnaire response options.

*Grade 6-8 students are not asked these questions in the HBSC Study. Therefore, these behaviours are only found in the Grade 9-10 risk behaviour categories.

[†]Denote risk behaviours that are a composite measure combining multiple HBSC Study questionnaire items.

[‡]Denote risk behaviours only found in the Grade 6-8 risk behaviour category based on the exploratory factor analysis.

Chapter 5

General Discussion

5.1 Summary of Key Findings

This thesis proposed two key areas of improvement in the study of school injuries: 1) the development of a better conceptualization of adolescent risk behaviours, which are known causes of school injury,^{1,2} and; 2) the adoption of population health theory³ to the evaluation of simultaneous and possible synergistic causes of school injury.

The first manuscript involved the creation of novel measures of multiple risk behaviour that built on the domains identified in the published,⁴ and widely utilized,⁵ CDC risk behaviour framework. This study found evidence supporting three different categories to conceptualize adolescent risk behaviour encompassed under the themes of *Overt Risk-Taking*, *Active Healthy Lifestyle Detriment*, and *Passive Healthy Lifestyle Detriment*. Relationships were observed between behaviours across multiple domains from the CDC framework. Our findings call for a refinement of the CDC risk framework to build on its theory-based underpinnings using the empirically tested results in this manuscript.

The second manuscript tested the direct relationship between each of the newly developed risk categories and school injuries, as well as the influence that a contextual determinant of injury (school climate) might have on those relationships. Young (Grades 6-8), overt risk-takers were identified as a high-risk group for unintended school injury ($OR_{high/low} = 1.61$; 95% CI = 1.30, 2.01) as well as several sub-types of school injury (e.g., serious school injuries: $OR_{high/low} = 1.87$; 95% CI = 1.32, 2.64). No statistically significant relationships were observed between multiple risk behaviour and injury among older students (Grades 9-10). School climate did not modify the relationship between risk behaviour and school injuries, and had highly variable and context-specific effects depending on student age, and the types of school injury assessed.

5.2 Limitations of the Thesis

Given the use of the same dataset, the two manuscripts in this thesis share limitations, and these will be discussed collectively.

First, there are inherent limitations with the use of cross-sectional data in regards to inferences about causality. The results of this study provide evidence of the associations between certain risk behaviour categories and injury, but these results are not sufficient to imply causation in the absence of longitudinal data that confirm the temporal directions of observed associations.

Second, the HBSC item used in this study to assess school injury asks students to recall injuries sustained within the last 12 months. Previous research has shown that adolescents can reliably recall injuries sustained up to three months prior, but begin to forget injury events that occur afterwards.⁶ However, this decline in recall is less noticeable for serious injuries and is believed to not occur in a systematic manner. Therefore, this limitation is likely non-differential in nature by the levels of exposure under study, and likely to bias any effect estimates such as odds ratios towards the null.

Third, the same HBSC item only asks students about their “*single, most serious injury*”. It is likely that students would have experienced multiple injuries throughout the year in different locations – only a fraction of which will have occurred in the school environment. Therefore, this measure may also bias the reported injuries to be the most serious school injuries – underestimating the proportion of minor school injuries and overestimating the proportion of serious injuries.

Fourth, it is possible that students may choose to answer questions about risk behaviours in a socially desirable manner. This under-reporting of risk behaviour is also believed to occur randomly among students and is therefore also likely to bias the results towards no effect.

Fifth, the classification of certain exposures involved the conversion of continuous measures into categories based on cut-off values. This may introduce exposure misclassification and could possibly under-estimate or over-estimate measures of association.

Sixth, the omission of several risk behaviours in the lower grades means that measures of multiple risk behaviour developed for students in grades 6-8 did not consider all of the risk domains outlined by the

CDC.⁴ The study of multiple risk behaviours was still grounded in the framework established by the CDC but we were unable to comprehensively address all of the identified adolescent domains of risk.

Seventh, because the full 2014 Canadian dataset only became available to HBSC investigators in June 2015, results were based on an interim HBSC dataset with lower representation from British Columbia and the three Northern Canadian Territories and did not have statistical weights available for use. Therefore, proportional estimates are not representative of the Canadian population in this age group. Following defense of this thesis and prior to submission, the analyses will be re-run with the final weighted 2014 dataset, although similar findings to that presented are expected.

5.3 Strengths of the Thesis

There are a number of strengths associated with this thesis.

First, the HBSC dataset is a large and national survey that has representation from a large proportion of the Canadian adolescent population. The anonymous report of health behaviours in the HBSC dataset also encourages accurate and honest responses, which is particularly important when studying risk behaviours.

Second, this thesis included two studies that were the first to measure multiple risk behaviour following an established risk framework⁴ that has categories covering the diverse areas of contemporary risk. This novel measure provides information about the current state of risk behaviour among Canadian adolescents by identifying clusters of problem behaviours and allowed for the development of a more comprehensive measure of association between multiple risk behaviour and injury. The large sample size available in the HBSC dataset also allowed the multiple risk behaviour measure to be developed and tested for construct validity in two independent samples.

Third, this thesis used a theoretical framework and empirically tested school climate as a contextual point of intervention to prevent future school injuries. Interventions that have targeted school climate in the past as an injury prevention program have seen mixed results. The studies in this thesis

support the findings from those interventions by showing the highly variable influence of school climate on injury outcomes.

5.4 Statistical Power

There is currently no consensus among researchers in regards to the suggested sample size required to perform exploratory or confirmatory factor analyses. Most studies use the 10:1 subject to item ratio as a general rule-of-thumb, while others suggest that the ‘nature of the data’ (i.e. communalities and cross-loadings) also plays a role in determining the required sample size.⁷ This study evaluated 22 risk behaviour items for Grades 6-8, 27 risk behaviour items for Grades 9-10, and 17 school climate items, all at the student-level. Because both exploratory and confirmatory factor analyses were assessed on risk behaviours and school climate measures for each grade group, the total number of students in each grade group were divided in half (Total Interim Cycle 7 Student Surveys: $N_{\text{exploratory}} = 8,714$, $N_{\text{confirmatory}} = 8,714$; Grades 6-8 $N_{\text{exploratory}} = 4,822$, $N_{\text{confirmatory}} = 4,821$; Grades 9-10 $N_{\text{exploratory}} = 3,893$, $N_{\text{confirmatory}} = 3,892$). This results in conservative subject to item ratios of 219:1 for Grades 6-8 and 144:1 for Grades 9-10. For the exploratory and confirmatory factor analyses of the School Climate Scale, the study will also have a conservative subject to item ratios of 283:1 for Grades 6-8 and 228:1 for Grades 9-10.

Several calculations were performed to assess the power to detect significant associations between various risk category exposures and school injury. In line with previous studies using the HBSC survey, a design effect size of 1.2 was used as an estimate of the school-level clustering. All calculations were made using power equations published by Kelsey *et al.* for cross-sectional studies.⁸

Separate calculations were made for each of the possible outcomes (any school injury, serious school injury, and sport injuries at school), each of the grade categories (Grades 6-8 and Grades 9-10), and individual-level exposures (i.e. multiple risk behaviour) with and without consideration for effect modification. Analyses assessing the main effects of adolescent multiple risk behaviour on school injuries had adequate power to detect associations of an odds ratio of 1.4 or greater. Similarly, analyses considering contextual effect modification also had adequate power to detect associations of an odds ratio

of 1.8 or greater. Admittedly, some of the analyses involved samples that had undergone multiple levels of stratification. Therefore, certain analyses only had power to detect larger effect sizes.

5.5 Future Research Directions

This thesis identified three categories of adolescent risk behaviour using the CDC risk behaviour framework. Although the studies within the thesis were limited to a small number of behaviours in some domains, the three categories developed are consistent with other studies that have found, separately, that risk behaviours cluster in similar and predictable ways.^{9,10} In contrast to previous studies, our use of a conceptual risk behaviour framework helped to ensure that the behaviours most closely associated with adolescent morbidity and mortality were included in our evaluation of risk behaviour clusters, including some types of behaviour that did not exist historically.^{11,12} The three conceptualizations of risk behaviour that were developed represent an opportunity for researchers to continue to evaluate the breadth of each category. Though this study focused solely on health risk behaviours, others have evaluated adolescent risk using illegal and deviant behaviours (i.e., truancy, theft, and social isolation) finding similar relationships with injury.¹³ Future investigations should evaluate how different indicators of risk behaviour relate to the categories of health risk behaviour that were identified in our research.

Research on the relationships between risk behaviours has recently re-emerged as an important area of epidemiological research with potential implications on etiological studies of various diseases, as well as investigations into adolescent behaviour modification.^{9,14} However, the use of these different conceptualizations of adolescent risk behaviour in the research of disease etiology is largely limited to study of Canadian populations and injury-related research.^{15,16} The three risk behaviour categories, and their relationships with injury should be re-evaluated in different countries and contexts to evaluate the generalizability of these findings. Researchers should also extend the use of these measures to evaluate relationships with other negative health outcomes that have suspected associations with adolescent risk behaviour, such as violence¹⁷ and mental health problems.¹⁸

Lastly, this thesis identified three clusters of risk behaviour that are believed to develop concurrently, based on Problem Behaviour Theory.¹⁹ Using this theory, researchers should continue to investigate potential upstream determinants, or risk factors, of these three categories of risk behaviour. Many interventions have attempted to address possible determinants of individual risk behaviours with modest success.²⁰ Few have attempted to address multiple risk behaviours at the same time and none have specifically targeted empirically tested clusters of risk behaviour.²¹ Investigation of risk factors of tested groups of risk behaviour may lead to the development of intervention programs that are more effective at reducing participation in these behaviours as well as their associated health consequences.

5.6 Public Health and Policy Implications

Public health interventions in the past have attempted to mitigate adolescent participation in individual risk behaviours through a variety of different means.²⁰ However, some have suggested that these interventions, which ignore the clustered nature of risk behaviours, may not capitalize on the ability to effectively address related behaviours at the same time.²² Prochanska showed examples of several studies where interventions targeting a certain risk behaviour increased the effectiveness of a subsequent intervention on a related risk behaviour compared to a control group (with no prior intervention on the initial risk behaviour).²¹ These studies provide early evidence suggesting that future public health interventions should target the categories of adolescent risk behaviour identified in this study. By addressing potential risk factors for each category of risk behaviour, public health practitioners will be able to prevent adolescents from participating in risk behaviours and prevent subsequent illness and injury.

Several interventions have shown a reduction in the number of risk behaviours and injuries occurring at school by improving the school's social climate.²³ However none have investigated the possible mechanism behind these results. This thesis evaluated a potential etiological theory to explain these findings by assessing school climate as an effect modifier of the relationship between risk behaviour and injury. We found that improved levels of school climate did not mitigate the association between risk behaviour and school injuries in any consistent or predictable manner. Positive school climate does not

appear to facilitate a more protective environment where high-risk students are at a reduced risk of sustaining an injury at school. The public health message stemming from this result should be that interventions targeting school climate in the future should address risk behaviour and injury reduction via a different mechanism. Improvements in school climate may, for example, prevent risk behaviours from developing and therefore prevent their associated injuries.

Young, overt-risk takers were identified as a high-risk group for general school injury, as well as several sub-types of school injury (including serious injuries). Given existing evidence suggesting that overt-risk taking behaviours are an early indication of later problem behaviours among young adolescents,²⁴ this study confirms the risk that these behaviours pose students in their current state. Public health interventions should utilize the array of overt risk-taking behaviours as early indications of subsequent problem behaviour and potential injury at school. Risk behaviour and injury prevention programs should then target high-risk students in this category as a priority, as opposed to more general population health approaches to injury control.

5.7 References

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Appendix A

The Health Behaviour in School-aged Children Study

The purpose of this chapter is to describe the Health Behaviour in School-aged Children Study (HBSC) used in this thesis.

The Health Behaviour in School-aged Children Study (HBSC)

All of the data in this thesis came from the Canadian Health Behaviour in School-aged Children Study (HBSC). The HBSC study involves an international collaboration between the World Health Organization and researchers from 43 different countries and regions. The goal of the HBSC study is to assess health behaviours and outcomes, as well as their contextual determinants, in school-aged children. The HBSC collects information about injury, self-perceived physical, mental, and social health, as well as attitudes and experiences in home, school, and play environments. Surveys in each member country include a standard set of ‘core’ items, which can be supplemented with additional items specific to the interests and needs of the member country.¹

Canada participated in its 7th cycle of the survey in the 2013-2014 school year. The Canadian HBSC survey includes information from all provinces and territories. The survey is administered to students from Grades 6 to 10 in schools designated as public or separate (Roman Catholic). The strength of this survey is its large sample of Canadian adolescents with representation from all the provinces and territories, as well as its extensive efforts at adequate representation of important demographic and geographic characteristics. This survey is ideal for the study of adolescent risk behaviours and injury in school environments.

Participants for the HBSC survey are sampled using a multi-level technique.² After provincial/territorial approval, all schools jurisdictions of public or Roman Catholic designation were invited to participate in the study. Among the school jurisdictions agreeing to participate, a sampling

frame of all eligible classes was created based on estimates of the number of Grade 6 to 10 classes available in each school. Classes were categorized in the sampling frame according to their school, school jurisdiction, community size, geographic location, main language of instruction, and their public or Roman Catholic designation. Students enrolled in private, special needs, or religious schools (except for publically funded Roman Catholic schools) were not included in this study. Classes were then cluster sampled to ensure proportional representation of those respective characteristics. After the initial sampling procedure, additional schools within clusters were sampled to rectify non-participation and to ensure adequate representation of the characteristics listed above. All students within a selected class were given approximately 45-70 minutes to complete approximately 260 items in the survey.

This thesis was completed using an interim Cycle 7 dataset consisting of 17,428 student responses from 227 schools. Although there was representation from all provinces and territories in the interim dataset, representation was lower from British Columbia and the three Northern Territories. Information about provincial weighting and response rates was also unavailable. As a result, proportional estimates are not representative of the Canadian population in this age group. Following defense of this thesis, the analyses will be re-run with the final weighted 2014 dataset, although similar findings to that presented are expected.

Study Ethics Approval

Cycle 7 of the HBSC Study (2013-2014) received ethics approval from the General Research Ethics Board at Queen's University (File # GEDUC-430-09). Consent for participation in this study was obtained from school boards, schools, parents, and students. The Canadian HBSC research team used either implicit or explicit consent procedures in different school boards depending on existing local practices. Student identities were not accessible and individual responses were kept confidential. Students sealed their completed surveys in envelopes to ensure confidentiality. Personal ethics clearance was also approved from the Health Sciences Research Ethics Board at Queen's University (ROME0 # 6013492).

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Appendix B

Development of the School Climate Scale

The purpose of this chapter is to describe the School Climate scale used in Manuscript 2 of this thesis.

Existing Measures of School Climate

Although there are several school climate scales that are frequently used in epidemiological and educational research, they all use similar measures and draw on the same aspects of school connectedness (i.e., safety, teaching and learning, relationships, and environmental-structural aspects of the school).¹ Previous HBSC studies have used a five-item scale to measure school climate and include items such as “the rules in this school are fair” and “my teachers are interested in me as a person”.² Torsheim et al published two scales to measure specific classmate- (four items, including “other students accept me as I am”) and teacher-support (four items, including “our teachers are nice and friendly”) related aspects of school climate.³ The United States National Longitudinal Study of Adolescent Health utilizes a five-item measure of school connectedness that is very similar to the five-item HBSC scale.⁴

Developing a New Measure of School Climate

The 2014 HBSC study has 17 items measuring different aspects of school climate that cover areas of student support, teacher support, and school capacity (i.e., ability to access extra help when needed). Many, but not all, of the items used in other school climate scales were available for use in this study. We had the opportunity to empirically derive and validate a measure of school climate using the 2014 HBSC study. We utilized a split-sampling method to perform both exploratory and confirmatory factor analyses to develop a school climate scale for use in this study. Separate analyses were performed for both grade groups (Grades 6-8 and Grades 9-10) due to established differences in perceptions of school climate, as

students grow older. Exploratory factor analysis was performed using maximum likelihood extraction with promax rotation and a factor loading cut-off of 0.40.⁵ Confirmatory factor analysis also used a maximum likelihood extraction method.

The result of the factor analyses was the same for both grade groups. We found a three-factor unique cluster solution with the first factor covering aspects of teacher support and school capacity (12-items), the second factor covering student support (three-items), and the third factor covering difficulties at school (two-items) (**Table 1**). Because the first two factors were only moderately correlated ($r = 0.58$), we decided to utilize only the first factor in our measure of school climate. Exploratory factor analyses showed that the three-factor solutions were a good fit for Grade 9-10 students (RMSEA = 0.077, 95% CI = 0.074, 0.080) and Grade 6-8 students (RMSEA = 0.073, 95% CI = 0.070, 0.076). Confirmatory factor analyses validated our factor structure for Grade 9-10 students (RMSEA = 0.075, 95% CI = 0.073, 0.078) and Grade 6-8 students (RMSEA = 0.073, 95% CI = 0.070, 0.075).

After factor analyses were performed, weights derived from the exploratory analysis were used to develop an aggregate score of school climate for each student. Aggregate scores were then averaged across all students within the same school to develop a school-level measure of school climate. Schools were then ranked according to these school-level measures and split into tertiles to identify schools as having relatively low, moderate, or high climate.

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Table 1. Results from exploratory and confirmatory factor analyses on 2014 HBSC measures of school climate for Grades 6-8 and Grades 9-10. Values under each factor represent factor loadings.

2014 HBSC Measure of School Climate	Grade 9-10 Students			Grade 6-8 Students		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
1. Teachers try to understand my perspective before offering alternatives.	0.67			0.62		
2. I feel that my teachers accept me as I am.	0.78			0.77		
3. I feel that my teachers care about me as a person.	0.81			0.84		
4. I feel a lot of trust in my teachers.	0.80			0.83		
5. When I need extra help, I can get it.	0.61			0.60		
6. My teachers are interested in me as a student.	0.78			0.75		
7. The rules in this school are fair.	0.53			0.48		
8. Most of my teachers are friendly.	0.63			0.62		
9. Our school is a nice place to be.	0.51			0.51		
10. I feel I belong at this school.	0.44			0.44		
11. I am encouraged to express my own views in my classes.	0.59			0.58		
12. Our teachers treat us fairly.	0.70			0.71		
13. The students in my classes enjoy being together.		0.71			0.72	
14. Most of the students in my classes are kind and helpful.		0.84			0.80	
15. Other students accept me as I am.		0.68			0.70	
16. I find schoolwork difficult.			0.72			0.71
17. I have more schoolwork than I can handle.			0.72			0.70
Eigenvalues	14.14	2.75	1.96	14.86	2.26	1.83
Cronbach's Alpha	0.91	0.80	0.68	0.92	0.79	0.67
RMSEA (Exploratory Factor Analysis)	0.077 (95% CI = 0.074,0.080)			0.073 (95% CI = 0.070, 0.076)		
RMSEA (Confirmatory Factor Analysis)	0.075 (95% CI = 0.073,0.078)			0.073 (95% CI = 0.070, 0.075)		
AGFI (Confirmatory Factor Analysis)	0.887			0.895		

Appendix C

Power Calculations

The purpose of this chapter is to demonstrate a sample power calculation and to show the statistical power available to detect significant differences in several analyses used in the second manuscript of this thesis.

Sample Power Calculation:

- Assessing the power to detect the relationship between multiple risk behaviour and any school injury, among students in Grades 6-8, while considering effect modification by school climate. Sample sizes were also reduced by a design effect size of 1.2 to account for clustering at the school-level. Equations published by Kelsey *et al.*²

Assumptions for Parameter Values:

- r = the proportion of those with low risk behaviour to those with high risk behaviour = 1
 \bar{p} = prevalence of any school injury among students in Grades 6-8 = 0.0744
 d^* = the smallest detectable difference that is expected to be observed = 0.0248
 n = number of high risk behaviour students (assuming 33% are in high climate schools) = 892

$$Z_{\beta} = \sqrt{\frac{n(d^*)^2 r}{(r+1)\bar{p}(1-\bar{p})}} - Z_{\alpha/2}$$

$$Z_{\beta} = \sqrt{\frac{892(0.0248)^2 1}{(1+1)(0.0744)(1-0.0744)}} - 1.96$$

$$Z_{\beta} = 1.46$$

Therefore, the power to detect a difference in proportion of 0.0248, given the parameters listed is almost 92.79%.

Power Calculations: Exposure – Multiple Risk Behaviour [No Effect Modification]

Study Outcome	Grade Level	Number of high risk students	Prevalence	OR	Smallest Detectable Difference	Power
Any School Injury	Grade 6-8	2678	0.0744	1.4	0.0248	93.28%
	Grade 9-10	2162	0.0713	1.4	0.0238	85.91%
Serious School Injury	Grade 6-8	2678	0.0288	1.6	0.0133	82.89%
	Grade 9-10	2162	0.0275	1.7	0.0143	81.76%
Sports Injury	Grade 6-8	2678	0.0341	1.6	0.0157	88.77%
	Grade 9-10	2162	0.0446	1.5	0.0178	81.07%

Power Calculations: Exposure – Multiple Risk Behaviour [With Effect Modification]

Study Outcome	Grade Level	Number of high risk students	Prevalence	OR	Smallest Detectable Difference	Power
Any School Injury	Grade 6-8	892	0.0744	1.8	0.0425	92.79%
	Grade 9-10	720	0.0713	1.8	0.0407	85.17%
Serious School Injury	Grade 6-8	892	0.0288	2.3	0.0227	81.77%
	Grade 9-10	720	0.0275	2.6	0.0244	80.93%
Sports Injury	Grade 6-8	892	0.0341	2.1	0.0242	80.42%
	Grade 9-10	720	0.0446	2.1	0.0316	82.85%

Appendix D

Ethics Approval



QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH
ETHICS BOARD-DELEGATED REVIEW

August 29, 2014

Mr. Jonathan Kwong
Department of Public Health Sciences
Queen's University

Dear Mr. Kwong

Study Title: EPID-479-14 Risk-taking behaviour and school injury in Canadian adolescents: Using novel population health theory to evaluate potential school-based contextual interventions

File # 6013492

Co-Investigators: Dr. W. Pickett, Dr. D. Klinger

I am writing to acknowledge receipt of your recent ethics submission. We have examined the protocol for your project (as stated above) and consider it to be ethically acceptable. This approval is valid for one year from the date of the Chair's signature below. This approval will be reported to the Research Ethics Board. Please attend carefully to the following listing of ethics requirements you must fulfill over the course of your study:

Reporting of Amendments: If there are any changes to your study (e.g. consent, protocol, study procedures, etc.), you must submit an amendment to the Research Ethics Board for approval. Please use event form: HSREB Multi-Use Amendment/Full Board Renewal Form associated with your post review file # 6013492 in your Researcher Portal (https://eservices.queensu.ca/romeo_researcher/)

Reporting of Serious Adverse Events: Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information. Serious Adverse Event forms are located with your post-review file 6013492 in your Researcher Portal (https://eservices.queensu.ca/romeo_researcher/)

Reporting of Complaints: Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.

Annual Renewal: Prior to the expiration of your approval (which is one year from the date of the Chair's signature below), you will be reminded to submit your renewal form along with any new changes or amendments you wish to make to your study. If there have been no major changes to your protocol, your approval may be renewed for another year.

Yours sincerely,

Albert J. Clark.

Chair, Health Sciences Research Ethics Board
August 29, 2014

Investigators please note that if your trial is registered by the sponsor, you must take responsibility to ensure that the registration information is accurate and complete



QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD

The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards and operates in compliance with the Tri-Council Policy Statement; Part C Division 5 of the Food and Drug Regulations, OHRP, and U.S. DHHS Code of Federal Regulations Title 45, Part 46 and carries out its functions in a manner consistent with Good Clinical Practices.

Federalwide Assurance Number: #FWA00004184, #IRB00001173

Current 2014 membership of the Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board:

Dr. A.F. Clark, Emeritus Professor, Department of Biomedical and Molecular Sciences, Queen's University (Chair)

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Dr. A. Singh, Professor, Department of Psychiatry, Queen's University

Dr. J. Walla, Assistant Professor and Clinical Geneticist, Department of Paediatrics, Queen's University and Kingston General Hospital

Ms. K. Weisbaum, LL.B. and Adjunct Instructor, Department of Family Medicine (Bioethics)

Dr. J. Whiteley, Community Member