Predicting Overweight and Obesity among Youth in Ontario, Canada: Evidence from Cross-sectional and Longitudinal Analyses

by

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This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

The manuscripts presented in this thesis are the work of Rachel Laxer, in collaboration with her co-authors and committee members. The co-authors include Dr. Scott Leatherdale, Dr. Ross Brownson, Dr. Marty Cooke, Dr. Joel Dubin, and Dr. Ashok Chaurasia.

The first manuscript was accepted for publication at BMC Public Health in January 2017. The second manuscript is under review in PLOS ONE, and the third manuscript has been submitted to the Journal of School Health. All manuscripts are presented in this dissertation as they have been accepted or submitted for publication to their respective journals.

For all manuscripts, Rachel Laxer was responsible for developing the research questions, conducting background research, leading the study designs, retrieving and managing the datasets, leading the statistical analyses, interpreting the results, and writing the initial drafts of the manuscripts. Dr. Leatherdale assisted with study design, provided guidance on statistical analyses and interpretation, and revised manuscripts for important intellectual content, lending his expertise. Dr. Brownson and Dr. Cooke revised all manuscripts for important intellectual content. Dr. Dubin provided guidance on statistical analyses, interpretation of results and revised manuscripts for intellectual content. Dr. Chaurasia provided guidance on statistical analyses, interpretation of results, and revised manuscripts for intellectual content.

ABSTRACT

The percentage of Canadian children and adolescents that are overweight or obese has increased dramatically since the 1980s, with approximately 25% of youth in Canada now characterised as overweight or obese. Canadian youth are engaging in multiple risk-taking behaviours, some of which are associated with an increased risk of overweight and obesity. The school environment has the potential to influence student body mass index (BMI) through implementation of comprehensive healthy school policies, programs, and practices in the domains of physical activity and healthy eating.

Guided by a socio-ecological framework, this dissertation research aimed to examine: (1) how modifiable risk behaviours cluster into unique behavioural patterns in youth, and how these behavioural patterns are related to BMI; (2) the effect of engaging in unique clusters of risky behaviours on youths' BMI trajectories; and, (3) the effect of modifying obesity-related school policies, programs, and practices on youths' BMI trajectories. Three manuscripts addressed these objectives using linked student- and school-level data from the COMPASS Study (COMPASS). The first manuscript represents a cross-sectional analysis (2012/13), while the second and third manuscripts were longitudinal (2012/13 to 2014/15) in nature.

The first manuscript assessed the prevalence and clustering of 15 modifiable risk behaviours using latent class analysis in a sample of 18,587 youth in grades 9 to 12. Four distinct classes emerged: *Traditional School Athletes, Inactive Screenagers, Health Conscious, and Moderately Active Substance Users*. Youth belonging to the *Traditional School Athlete, Inactive Screenager, and Moderately Active Substance User* clusters were all significantly more likely to be overweight or obese, compared to the *Health Conscious* group.

The second manuscript examined the effect of engaging in the four clusters of risky behaviours at baseline on youths' BMI trajectories, using a linked longitudinal sample of 5,084 students in Grades 9 and 10. Using linear mixed effects models, results identified a significant difference in BMIs only at baseline in the four clusters; despite these differences, BMI increased across all clusters annually by the same amount.

The third manuscript examined the effect of modifying physical activity and nutrition-related programs, policies, and practices on BMI trajectories using a linked longitudinal sample of 4,951 students in

Grades 9 and 10 attending 41 COMPASS schools. Between 2012/13 and 2013/14, 26 of 41 schools implemented distinct new programs or policies, none of which used a Comprehensive School Health Approach. Results indicate that none of these school modifications were associated with improved or reduced BMI trajectories.

Findings of this dissertation research have implications for future public health and school-based interventions, and highlight the need for future research in this area, particularly focused on a Comprehensive School Health approach to obesity prevention. COMPASS is uniquely positioned to evaluate similar naturally occurring school-based interventions in a cost-effective and efficient, yet scientifically robust manner by following the same students as they progress through school and are exposed to a changing school environment.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

COMPASS: no longer an acronym, rather the name of the host study. In the past, "COMPASS" was used to represent: the **C**ohort Study on **O**besity, **M**arijuana use, **P**hysical activity, **A**lcohol use, **S**moking, and **S**edentary behaviour

BMI: body mass index

SEM: Socio-ecological model

MVPA: Moderate-to-vigorous physical activity

Cq: COMPASS Student questionnaire

SPP: COMPASS school policies and practices questionnaire (completed by each COMPASS school administrator)

SSB: Sugar-sweetened beverage

OPHS: Ontario Public Health Standards

CSH: Comprehensive School Health

WHO: World Health Organization

CDC: Centers for Disease Control and Prevention

SES: socioeconomic status

95% CI: 95% Confidence Interval

SE: Standard Error

LCA: Latent Class Analysis

Chapter 1:

General Introduction

1.1 Overview

Approximately 25% of Canadian children and adolescents are overweight or obese, rates triple those just three decades ago (Roberts, Shields, de Groh, Aziz, & Gilberta, 2012). Age-related increases in obesity are concerning, as they are associated with multiple chronic diseases and psychosocial outcomes, including cardiovascular disease, cancer, diabetes, and depression (Daniels, et al., 2005; Sjoberg, Nilsson, & Leppert, 2005). Since health behaviours and obesity established during adolescence tend to track into adulthood (Freedman, Khan, Serdula, Dietz, Srinivasan, & Berenson, 2005; Whitaker, Wright, Pepe, Seide, & Dietz, 1997), it is critical to promote healthy behaviours associated with healthier body weight and overall health among youth. Due to the numerous health consequences and the significant costs associated with overweight and obesity (Katzmarzyk, 2011), it is important to understand its determinants to deliver appropriate prevention and treatment. While there are two primary energy-balance related behaviours that, if unbalanced, can lead to changes in weight status (Janssen, Katzmarzyk, Boyce, King, & Pickett, 2004), there are other behavioural and contextual factors that must be considered when exploring obesity in youth (Dietz & Gortmaker, 2001).

Health agencies and authorities have been focusing on policy and population-wide programming as effective strategies to curb overweight and obesity, through population-wide improvements to particular obesity-related health behaviours (CDC, 2013). However, multiple lifestyle and other factors extraneous to the individual, such as the environment, can also contribute to an increased risk of overweight and obesity, making it is an exceedingly complex condition to study. The complexity of the determinants of overweight and obesity can be described by the socio-ecological model, a highly adaptable framework that suggests multiple levels of influence that contribute to the development of overweight and obesity (Bronfenbrenner, 2000; McLeroy, Bibeau, Steckler, & Clanz, 1988).

There is a need to identify and evaluate population health interventions that aim to reduce overweight and obesity among youth, and set children and youth on more positive trajectories by improving health behaviours, maintaining healthy weights and ultimately reducing the risk of developing chronic diseases. Public health programs and policies targeting youth health behaviours may help prevent the onset or reduce the prevalence of overweight and obesity. This is important, given

that prevention offers a less expensive approach when compared to obesity treatment (Kesten, Griffiths, & Cameron, 2011). Successful prevention can be achieved through population-based initiatives, nationally and through settings-based approaches (WHO, 2008). Some programs have been designed for and implemented within the school setting, since schools are an environment with the potential to reach most youth. Despite this, evidence on the success of school-based program and policy interventions on youths' body mass index (BMI) has been mixed (Katz, O'Connell, Njike, Yeh, & Nawaz, 2008). The reasons for this are not well understood, but might be attributable to methodological limitations (Kropski, Keckley, & Jensen, 2008), or to a limited focus on just one policy (e.g., a food and nutrition policy only), when the overall policy environment may be more important (Nanney, et al., 2010).

Robust research on both the individual and environmental determinants of overweight and obesity among youth in Ontario is lacking. By increasing our understanding of the specific behavioural determinants of overweight and obesity, school policies and programs might be more effectively designed to target youth at greatest risk. This research aims to identify individual and school-level determinants of overweight and obesity, and the interactions between these determinants and students' BMI. It is hoped that results from this dissertation result in recommendations for obesity prevention interventions for high school students in Ontario, which may be relevant in other school contexts outside of Ontario.

1.2 Scientific and Public Health Relevance and Implications

There is general consensus in Canada and worldwide that the increasing prevalence and consequences of overweight and obesity require broad solutions that extend beyond individual behaviour change. This dissertation research explored how different risky behavioural profiles in youth are related to overweight and obesity, and the effects that behaviours and contextual factors have on youths' BMI trajectories. Research findings are relevant to public health officials and school stakeholders, as they may provide evidence to inform new policies, programs, or the addition of new resources to the school environment to improve physical activity and healthy eating opportunities to ultimately slow BMI trajectories.

Empirical evidence has shown that individual-based approaches to obesity prevention and treatment have had limited impact on children and youth, whereas population-level intervention strategies that change the environments surrounding youth may have a greater impact. One such environment amenable to change and in which youth spend a large part of their day is the school. Most research to date has focused on the cross-sectional associations between student- or school-level

characteristics and overweight and obesity, thereby leaving a gap in our knowledge with respect to the causal relationships between these characteristics and BMI or BMI trajectories. Identifying which school characteristics are effective at slowing BMI trajectories in youth is important for school stakeholders and planners aiming to modify programs, policies, or develop health behaviour interventions. By systematically collecting ecological measures on program and policy implementation within schools, and linking this information with student behavioural data, results of this research were intended to contribute the evidence needed to understand the contribution of both student and school-level factors on BMI trajectories to make recommendations for future policy and school-based programming. Results from this dissertation will also contribute to the growing knowledge on youth overweight, obesity, and BMI trajectories, and will help to inform decision- and policy-makers on how to improve existing school-based programs and policies among youth in Ontario.

1.3 Thesis Purpose and Objectives

At a high level, this dissertation research aimed to examine how:

1. modifiable health behaviours cluster, and how the clustered behavioural patterns are related to overweight and obesity;
2. engaging in unique patterns of behaviours during adolescence can predict BMI trajectories; and
3. changes to obesity-related school programs and policies can predict BMI trajectories in youth.

1.3.1 Thesis Organization

This thesis is made up of three separate but related studies that were prepared for publication. Studies are preceded by this general introduction, and a general literature review that identified gaps in the literature that framed the research questions (Section 2.7). Chapter 3 provides an overview of the COMPASS host study that was used to answer the research questions. Finally, study findings all summarized and contextualized in a general discussion (Chapter 7:
General Discussion), which includes strengths and limitations, implications for school and public health, as well as directions for future research.

Chapter 2:

Literature Review

2.1 Overview

This chapter addresses the prevalence and consequences of being overweight and obese during adolescence, with focus on Canadian youth (2.3), individual-level factors associated with overweight and obesity (2.4.1), the co-occurrence of risky health behaviours among youth (2.4.2), the influence of the school environment on youth health behaviours and outcomes (2.4.3.1), and the rationale for focusing on students in high school (2.5). It describes the socio-ecological framework that was used to guide this dissertation research (Figure 1) and the Comprehensive School Health framework (2.4.3.1.1). This chapter concludes with a summary of key findings (section 2.6) and the identified gaps in the literature (section 2.6) that led to the formulation of three research questions of interest. Due to the broad scope of the research in this field and the heterogeneity of study designs, measurement of exposure, and outcome measures, it was too difficult to provide an exhaustive and systematic review of the literature on the causes, correlates, and outcomes of obesity; instead, a detailed and critical summary of the literature and identified gaps in the research are presented below.

2.2 Key Definitions

The focus of this dissertation is on *adolescents* in grades 9 to 12, referred to throughout the thesis as *youth*. The true definition of *overweight* is an individual that has an excess body weight for a particular height from fat, muscle, bone, water, or a combination, whereas *obesity* is the condition of excess body fat (US Department of Health and Human Services, 2010). For the purpose of this dissertation, I focused on *body mass index (BMI)*, which is calculated as weight divided by height squared (BMI = kg/m^2), and is commonly used to estimate weight status or as an indicator of overweight and obesity. Pediatric *obesity* will be defined as BMI that is above the recommended cut-off point for a specific age and sex, as defined by Cole et al. (2000) and used in many other population-based studies in Canada and internationally (Cole, Bellizi, Flegal, & Dietz, 2000).

Physical activity is defined as bodily movements produced by skeletal muscles that result in energy expenditure (Casperson, Powell, & Christenson, 1985). Physical activity is a behaviour that can be conceptualized on a continuum from minimal (inactive) to maximal (highly active) and can include both planned and spontaneous activity, or any activities that increase the heart rate through sports, activities, play, or active transportation. *Sedentary behaviours* are a class of behaviours that can coexist

with and are considered independent of physical activity, ranging from unproductive screen-based behaviours (e.g., watching television (TV) and playing video or computer games), to more productive behaviours (e.g., reading or doing homework) (Tremblay, et al., 2011).

Obesogenic environments are those that promote the consumption of energy dense foods and dissuade participation in physical activity (Swinburn, Egger, & Raza, 1999; Kirk, Penney, & McHugh, 2010). *School programs and policies* are broadly defined as any school-based intervention that is aimed at changing health behaviours, such as creating or enhancing a breakfast program to increase fruit and vegetable consumption, or enacting a policy to decrease time spent on computers in an effort to decrease screen time. A *policy* can be further defined as written procedures or guidelines shared with students and staff, related to promoting healthy behaviours.

2.3 Overweight and obesity among youth in Canada

The problem of overweight and obesity is increasing worldwide and is a global health concern (Ogden et al., 2014; Wechsler et al., 2004). According to data from the 2007-09 Canadian Health Measures Survey (CHMS), 31% of boys and 26% of girls 15-19 years of age were overweight or obese (Roberts, Shields, de Groh, Aziz, & Gilberta, 2012; Shields & Tremblay, 2010). Similarly, in the United States, 14.9% of children and youth aged 2-19 years were overweight and 16.9% were obese in 2008 (Ogden, Carroll, Kit, & Flegal, 2008). These rates are three times higher than they were just 30 years ago (Ogden et al., 2008; Roberts et al., 2012). The etiology of obesity is complex and can be attributed to a number of factors, including both non-modifiable (genetic) and modifiable (social, behavioural, and environmental). However, the rapidly increasing prevalence of overweight and obesity suggests that modifiable behaviours may be contributing more than the non-modifiable factors, and that the environments influencing these behaviours may be implicated as a major driving force of this obesity "epidemic" (Hill, Wyatt, Reed, & Peters, 2003).

2.3.1 Concerns and consequences of overweight and obesity

Age-related increases in obesity are cause for concern, as they are associated with an increased risk of several chronic diseases, some of which only appear in adulthood, but many of which are beginning to develop in younger ages (Glavin et al., 2014). Medical consequences of overweight and obesity include orthopaedic complications, metabolic disturbances, type 2 diabetes, poor immune function, impaired mobility, increased blood pressure and hypertension (Daniels, 2006; Wabitsch, 2000), some types of cancers (Calle & Thun, 2004), and psychosocial problems, including low self-esteem, social alienation, lack of self-confidence, and depression (Dietz, 2004). Most notably,

overweight and obesity in adolescence is associated with obesity in adulthood (Singh, Mulder, Twisk, Van Mechelen, & Chinapaw, 2008).

The burden of obesity is not only associated with physical and psychological consequences, but there are also substantial health care costs, attributed to both chronic diseases as well as lost productivity through greater absenteeism (Katzmarzyk, 2011). In a review by Withrow and Alter on the economic burden of obesity worldwide, individuals with obesity had medical costs 30% higher than their non-overweight peers (Withrow & Alter, 2011). In Canada, the costs associated with obesity in 2009 were estimated to be $4.5 billion ($1.6 billion in direct, $2.87 billion in indirect costs), representing 2.2% of the total health care costs in Canada (Katzmarzyk, 2011). Obesity-related diagnoses result in greater healthcare service utilization, decreased quality of life (Fontaine & Barofsky, 2001), shortened lifespans (Peeters et al., 2003), and negative stereotypic and shaming of overweight and obese youth (Must & Strauss, 1999).

2.3.2 Measurement of obesity

Overweight is defined as having excess body weight for a particular height from fat, muscle, bone, water, or a combination, whereas obesity is the condition of excess body fat (US Department of Health and Human Services, 2010). There are noninvasive methods to measure fat mass, including underwater weighing, bioelectric impedance, skin-fold calipers, as well as subjective (self- or proxy-report) measures of height and weight to calculate body mass index (BMI). Despite its simplicity, BMI is the most commonly used measure of overweight and obesity, especially in youth and in large population-based studies (Sweeting, 2007). BMI is measured as the ratio of height to weight-squared, and is commonly used to evaluate a person's health risk (Spruijt-Metz, 2011). International age- and gender-specific BMI cutpoints have been developed by the Childhood Obesity Working Group of the International Obesity Task Force, and can classify youth as normal, overweight, or obese. Cutpoints were derived from a large international sample using regression techniques, passing a line through the adult health-related cutpoints at 18 years. Youth with BMI values corresponding to an adult BMI of < 18 kg/m^2 are considered underweight, 18 to 24.9 kg/m^2 are considered normal, 25 to 29.9 kg/m^2 considered overweight, and over 30 kg/m^2 as obese (Cole, Bellizi, Flegal, & Dietz, 2000). These values are related to the risk of morbidity and mortality that accompanies excess weight. Although BMI might not the best indicator of weight status in any population, it is has been found to be an appropriate measure for population studies on obesity in youth (Leatherdale & Laxer, 2013) and is useful for surveillance and comparisons across studies.

There are some limitations to using BMI, such as classifying weight status based on only height and weight, without consideration to body composition or fat distribution, both important in identifying

health risks associated with obesity. For example, a body builder with a high amount of muscle mass would be classified as obese based on his/her BMI alone, but might have fewer health risks than an individual of the same BMI but with a body composition largely made up of fat. Despite these limitations, BMI is widely used and has utility for policy and clinical practice, because the more precise methods to measure body composition are too complex and expensive for public health practice and population-based research (Spruijt-Metz, 2011).

2.4 An ecological approach: the socio-ecological model

Ecological models describe behaviours as being influenced by the individual and the multiple contexts within which the individual is situated. For youth, this might refer to the school, home, and surrounding community environments, all of which are influenced by people, programs, policies, and the physical structures (i.e., built) environment (McLeroy, Bibeau, Steckler, & Clanz, 1988). The causes of overweight and obesity in childhood and adolescence can involve interactions among multiple factors, including personal (i.e., behavioural patterns and preferences), environmental (i.e., home, school, surrounding community), societal (e.g., peer influences, social network), political (i.e., laws and rules), and physiological (e.g., genetic predisposition) (Pratt et al., 2008). The complexity of these interventions and the public health significance of obesity in youth suggest that the multiple levels of influence leading to overweight and obesity should be examined together in an ecological model.

Socio-ecological models (SEM) have been designed to provide a framework to conceptualize how an individual's behaviours are developed and influenced by interactions between their own individual characteristics and the contexts in which they are situated (Bronfenbrenner & Morris, 1998). Through SEMs, researchers might better understand the mechanisms and ways to modify health behaviours, understanding the importance of consideration to each of the larger contexts. The tenets of ecological theory and SEM specifically suggest that an individual can behave differently when exposed to different environments, but that different people will behave differently within the same environment (McLeroy et al., 1988; Giles-Corti, Timperio, Bull, & Pikora, 2005). An important aspect of the SEM is that, for individuals to effectively change their health behaviours and outcomes, contextual surroundings, including their immediate environments and policies, must be conducive to such health behaviour change through the necessary supportive resources. Therefore, external influences must be considered in conjunction with an individual's innate tendencies when the goal is to change behaviour (Davison & Birch, 2001).

Levels in the SEM are seen as nesting dolls, with successive concentric circles inclusive of those within or those that come after, and at times, distinction between levels might not always be clear.

Similar to Aristotle's idea that "the whole is greater than the sum of its parts," interventions might be more effective with a basic understanding of each level of the SEM on its own, followed by understanding its interaction with other levels. Most simplistically, the four levels included in the SEM are (1) *individual factors* – characteristics of the individual, including genetics, skills, and attitudes, as well as family, friends, peers, and social support, (2) *behavioural settings* – the environment within which youth spend their time and in which behaviours might be influenced, (3) *macro-level environments* – the factors that make up the physical environment to influence physical activity, diet, or sedentary behaviours, and (4) *social norms and values* – the rules, laws, and regulations that can affect all levels (see Figure 1). Many interventions to date have focused on just one level of the SEM. However, just as overweight and obesity are the result of complex and interrelated factors, its prevention must involve multi-faceted action based on the ecological approach and the SEM. Knowing that the environment has the potential to influence the behaviours that occur within it, researchers have a strong theoretical rationale for developing intervention strategies for health enhancing practices (Sallis, Owen, & Fisher, 2008).

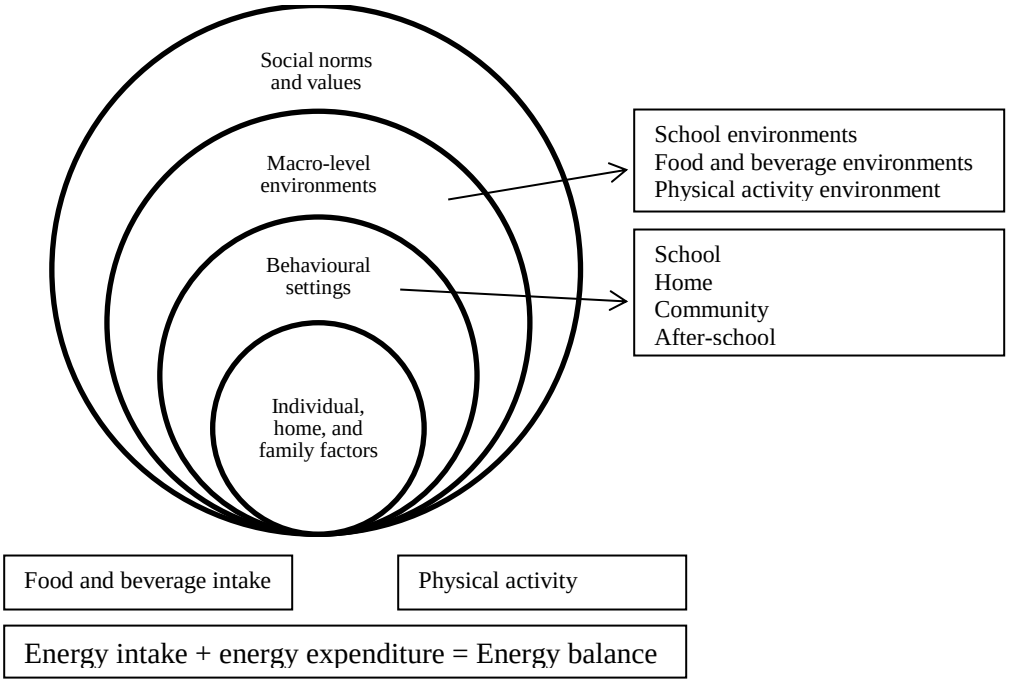

Figure 1. Socioecological framework relevant to youth obesity

The school environment is considered a relevant behavioural setting, with potential to largely influence youths' behavioural development. Youth spend approximately 25 hours per week and 44 weeks per year in school, where they can be influenced by interactions with their teachers, administrators, and peers, as well as with the wider school system, through policies, programs, and

resources (Kubik et al., 2003). Targeting youth behaviours through interventions that consider all levels of the SEM, including the school and its policies, practices, and environment, might be more effective when guided by the SEM (Bronfenbrenner, 2000; Hamre et al., 2006; McLeroy, Bibeau, Steckler, & Clanz, 1988; Stokols, Allen, & Bellingham, 1996).

2.4.1 Individual-level factors and modifiable health behaviours

The recent increase in obesity prevalence among youth can be partially explained by factors that influence energy expenditure or energy intake, including high energy density diets, high levels of sedentary behaviour, and low levels of physical activity (Janssen, Katzmarzyk, Boyce, King, & Pickett, 2004; Rennie, Johnson, & Jebb, 2005). Over the past 30 years, there have been increases in consumption of energy-dense, high fat foods, along with reduced physical activity, possibly attributable to the increased time spent watching television and playing video games, decreased active transportation to schools, or decreased opportunities for physical activity in schools (Janssen et al., 2004; Marshall, Biddle, Gorely, Cameron, & Murdey, 2004). Given the rate at which obesity has increased over the past three decades, researchers are focusing more on the modifiable risk factors as causes of obesity (Marti, Moreno-Aliaga, Hebebrand, & Martinez, 2004). Indeed, many of these modifiable correlates of obesity are well understood, and epidemiological studies have identified that some of the major contributors to overweight and obesity in youth include excess screen-time, insufficient physical activity, and poor diets (Spruijt-Metz, 2011; Davison & Birch, 2001). While each of these three obesity-related modifiable behaviours are individually important and contribute to an increased risk overweight and obesity, having more than one risk factor might amplify an individual's risk of overweight and obesity (Crespo et al., 2001; Leatherdale & Rynard, 2013; Leatherdale, 2015; Leech et al., 2014).

To promote healthier behaviours within the Canadian population, several groups have developed recommendations and guidelines for youth that, if achieved, can result in an overall improvement to youth health (Canadian Society for Exercise Physiologist [CSEP], 2014a; CSEP, 2014b). Guidelines were designed to provide authoritative advice on how to establish and maintain healthy behaviours that reduce individual risk of chronic disease and obesity (Meija et al., 2012). However, youth rarely meet more than one guideline or recommendation, if they meet any at all, making it difficult to establish if there is a causal association between achieving the guidelines or recommendations and a reduced risk of overweight and obesity. Based on international research, the achievability of the guidelines themselves might be called into question, since 50% of Swiss adolescents met none of the health behaviour guidelines or recommendations, one third met only one guideline, and less than 2% met all three guidelines (Meija et al., 2012). Recently in Ontario,

Leatherdale reported that only 47% of youth are meeting physical activity guidelines, 3% are meeting the sedentary behaviour guidelines, and only 5% are consuming an adequate amount of fruit and vegetables as per Canada's Food Guide recommendations (Leatherdale, 2015). Since compliance to guidelines and recommendations tends to decrease with age (Sanchez et al., 2007), there is a need to improve health behaviours during adolescence when health behaviours are established.

2.4.1.1 Physical Activity

Physical activity is an important component of a healthy lifestyle, and is one of the most important factors in long-term weight management and obesity prevention (Patrick et al., 2004; Loprinzi, Cardinal, Loprinzi, & Lee, 2012; Must & Tybor, 2005). Being physically active during adolescence is also associated with other positive health outcomes (Nelson, Gordon-Larsen, Adair, & Popkin, 2005), including higher self-esteem and interaction with peers, fewer psychosocial problems, reduced stress, and improvements to musculoskeletal, metabolic and cardiovascular health (Janssen & LeBlanc, 2010). For youth to experience health benefits of physical activity, the activity must be of at least moderate intensity, and should be accumulated for a minimum of 60 minutes, every day of the week (Tremblay et al., 2011c). There is a dose response relationship between physical activity and youth health; an increase in physical activity time is associated with an increase in health benefits (Janssen & LeBlanc, 2010; Strong et al., 2005).

Both active transportation and participation in organized sport can contribute to overall levels of physical activity and reduced overweight and obesity. Active modes of transportation, including walking, cycling, or wheeling (skateboarding or scootering), can serve as important (and more relevant) sources of physical activity for children and youth (Faulkner, Buliung, Flora, & Fusco, 2009), although results are not strong or conclusive, might relate to changes in BMI (Faulkner et al., 2009). On the other hand, participation in after school sports was associated with a decreased risk of obesity in a group of 10 to 17 year olds, compared to their peers who did not participate in sports (Story, Nanney, & Schwartz, 2009).

Despite the positive health consequences associated with physical activity in youth, rates of inactivity worldwide are high (Butcher, Sallis, Mayer, & Woodruff., 2008; Jekauc, Reimers, Wagner, & Woll, 2012; Pate et al., 2002), with most children and adolescents not accumulating sufficient amounts of physical activity for optimal health. Evidence from both cross-sectional and longitudinal research has shown consistent declines in physical activity, higher among females than males (Aaron, Storti, Robertson, Kriska, & Laporte, 2002; Nelson, Neumark-Sztainer, Hannan, Sirard, & Story, 2006). The decrease in physical activity levels might be attributable to a decrease in physical education as children transition into secondary schools, or to the greater appeal of engaging in screen-time as

alternative activities (Craig, Cameron, Russel, & Beaulieu, 2001). To protect youth from declining levels of physical activity, thereby preventing chronic disease, it is important to promote regular physical activity during childhood and adolescence.

Most of the evidence on the relationship between physical activity and obesity has been cross-sectional, with limited longitudinal research (see Appendix B, Table 11 for some examples). For the most part, the longitudinal studies have shown positive effects of physical activity on BMI (Berkey, Rockett, Gillman, & Colditz, 2003; Burke et al., 2006; Boone, Gordon-Larsen, Adair, & Popkin, 2007; Gordon-Larsen, Adair, & Popkin, 2002).

Physical Activity Guidelines

The first Canadian physical activity guidelines for children and youth were published in 2002 (Health Canada, 2002), to provide recommendations for children and youth, regardless of their physical activity levels, to increase the time they spend in moderate-to-vigorous physical activity (MVPA) by 30 minutes each day, and over 5 months, by an additional 90 minutes. The guidelines were updated in 2011 by physical activity experts using evidence from several systematic reviews, for youth to accumulate at least 60 minutes of MVPA daily, and to incorporate strength and flexibility training (see guidelines, Appendix A Figure 10) (Tremblay et al., 2011c; Janssen, 2007). According to objective measures from the Canadian Health Measures Survey, only 9% of boys and 4% of girls in Canada accumulated at least 60 minutes of MVPA on at least 6 days of the week (Garriguet Janssen, Craig, Clarke, & Tremblay, 2011). Non-compliance to physical activity guidelines tends to increase with age (Pate et al., 2002), and is more common among adolescents who are female, older, immigrants, tobacco users, overweight or obese, consume fewer fruits and vegetables, report having low level of satisfaction with life, report low levels of academic achievement, and spend a lot of time studying (Galan et al., 2014).

2.4.1.2 Dietary Behaviours

The majority of youth have suboptimal eating patterns and do not follow critical dietary recommendations (Ha, Bae, Urrutia-Rojas, & Singh, 2005; Diethelm et al., 2011). In the US, 40% of adolescents' daily food intake is of low nutritional value, including sugar-sweetened beverages and foods prepared outside of the home (Reedy & Krebs-Smith, 2010), while 25% of calories that Canadian youth consume come from added sugars (Langlois & Garriguet, 2011). This is problematic, because overconsumption of low-nutrient, energy-dense foods is a strong predictor of overweight and obesity in youth (IOM, 2012). Since three in ten adolescents have energy intakes that exceed the recommendations and their actual dietary needs (Rossiter, Evers, & Pender, 2012), and because eating behaviours established early in life tend to persist into adulthood (Field, Gillman, Rosner, Rockett, &

Colditz, 2003), it is important to target dietary behaviours in obesity and chronic disease prevention (Hamre et al., 2006).

The Centers for Disease Control and Prevention (CDC) recommend that youth consume a minimum of five servings of fruits and vegetables daily to reduce their risk of nutrition-related chronic diseases, all-cause mortality (Wang et al., 2014), certain types of cancer, and overweight and obesity (Field et al., 2003). However, only 22% of US secondary school students reported consuming this amount. The recommendations in Canada's Food Guide, on the other hand, are for youth to consume 7-8 servings of fruits and vegetables daily. In 2011, less than 6% of boys and 8% of girls were meeting these recommendations (Leatherdale & Rynard, 2013).

The association between sugar-sweetened beverage (SSB) consumption and BMI has been supported by a number of studies (Te, Mallard, & Mann, 2013; Ludwig, Peterson, & Gortmaker, 2001; Berkey, Rockett, Field, Gillman, & Colditz, 2004). SSBs are defined as drinks with caloric sweeteners, including soft drinks, fruit drinks or punches, sport drinks, tea/coffee drinks, energy drinks (carbonated with large amounts of caffeine, sugar, and other ingredients) and sweetened milk/alternatives (Collison et al., 2010), that tend to be available for purchase within and close to schools (Hebden, Hector, Hardy, & King, 2013). Consumption of SSBs has increased dramatically in the last decade, concurrent with the increase in overweight and obesity (Collison et al., 2010). Masse and colleagues found that the availability of SSBs was positively associated with both moderate and high consumption and with obesity, but not overweight (Masse, de Niet-Fitzgerald, Watts, Naylor, & Saewye, 2014).

Fast food, described as being high in calories and low in nutrient quality, is associated with an unhealthy weight gain. Among youth aged 11 to 18 years, boys and girls regularly eating fast food tended to consume an additional 800 and 660 calories per week, respectively, equivalent to weight gain of ten pounds per year (Niemeier, Raynor, Lloyed-Richardson, Rogers, & Wing, 2006; French, Story, Neumark-Sztainer, Fulkerson, & Hannan, 2001). There is also a decline in the frequency of breakfast consumption among adolescents (Timlin, Pereira, Story, & Neumark-Sztainer, 2008; Rampersaud, Pereira, Girard, Adams, & Metzl, 2005), which is problematic given the dose-response relationship between breakfast skipping and body weight (Timlin et al., 2008).

Many of these shifts in dietary behaviours can be described by lifestyle, developmental, social, and environmental changes, including declines in fruit and vegetable consumption, milk and fruit juices, and an increase in quantity of SSBs and other snack foods (Story, Neumark-Sztainer, & French, 2002). Youth are gaining more autonomy in their food choices, and their immediate surroundings might be most influential of their dietary choices than their parents and teachers (Story, Sallis, & Orleans, 2009; Taylor, Evers, & McKenna, 2005). Not only are students exposed to a wide variety of less

healthful foods and beverages within schools, such as SSBs, pizza, chips, and French fries (Briefel, Crepinsek, Cabili, Wilson, & Gleason, 2009; Rovner, Nansel, Wang, & Iannotti, 2011), but the environments outside of the school also offer less healthful food options (Masse et al., 2014), with an often-high clustering of less healthful food retail places around schools (Laxer & Janssen, 2013).

Dietary Guidelines/Recommendations

Canada's Food Guide was developed by the federal government to assist Canadians in making healthy food choices to reduce their risk of nutrition-related chronic diseases and obesity (Storey et al., 2009) by ensuring the population consumes the appropriate nutrients within a constrained and conservative number of calories. While the Food Guide recommends that boys and girls aged 14 to 18 years of age consume eight and seven daily servings of fruits and vegetable, respectively, (Health Canada, 2007), 2011 Canadian data suggest that less than 6% of boys and 8% of girls in grades 9 to 12 are meeting this recommendation (Leatherdale, 2015; Leatherdale & Rynard, 2013). This is concerning, as fruit and vegetable intake is negatively associated with BMI in male youth (Janssen et al., 2004), and compliance to Food Guide recommendations tends to worsen with age (Rossiter, Evers, & Pender, 2012). The CDC recommends consuming five or more fruits and vegetables per day to reduce the risk of chronic disease (CDC, 2005), a target that may seem more attainable for youth. Data from the 2013 Canadian Community Health Survey indicated that only 41% of boys and 46% of girls consumed five or more fruits and vegetables each day. Canada's Food Guide Recommendations for youth can be found in Appendix A (Figure 12).

2.4.1.3 Sedentary Behaviour

Another modifiable behaviour associated with overweight and obesity that has been steadily increasing over the past three decades is sedentary behaviour (Hills, King, & Armstrong, 2007; Strong et al., 2005; Ullrich-French, Power, Daratha, Bindler, & Steele, 2010; Berkey et al., 2000). Until recently, sedentary behaviour was considered to be the absence of physical activity. Now, sedentary behaviour is classified as a behaviour independent of physical inactivity, including screen time behaviours, reading, and time spent doing homework, all of which may be increasing risk of overweight, obesity, and other chronic diseases (Carson & Janssen, 2011; Leatherdale & Wong, 2009). In fact, sedentary behaviour can co-exist with physical activity, and the two behaviours might even be unrelated or weakly associated (Marshall, Biddle, Gorely, Cameron, & Murdey, 2004; Sallis, Prochaska, & Taylor, 2000), thus suggesting that the two behaviours are independent risk factors for overweight and obesity with their own health outcomes and consequences (Van der horst, Chinapaw, Twisk, & van Mechelen, 2007). Sedentary behaviours can be distinguished as productive (e.g.,

homework, reading) or unproductive (e.g., watching TV/videos, playing on the computer/video games); unproductive sedentary behaviours tend to be more closely associated with negative health outcomes than productive sedentary behaviours (Leatherdale & Wong, 2009; Martinez-Gomez, Tucker, Heelan, Welk, & Eisenmann, 2009).

In their review of sedentary behaviours and obesity development in children and youth, Rey-Lopez and colleagues found that most studies identified a positive association between TV and adiposity (Rey-Lopez, Vicente-Rodriguez, Biosca, & Moreno, 2008). Among 153 middle school students aged 11-15 years, those meeting the daily recommendations of two hours or less of screen time had a significantly lower BMI compared to students exceeding the recommendations (Ullrich-French et al., 2010). Similarly, the prevalence of obesity was lowest among children who watched less than one hour of TV per day and highest among those watching more than four hours per day (Crespo et al., 2001; Gortmaker et al., 1996), with more sedentary time associated with BMI increases in females (Berkey et al., 2000). There are several potential mechanisms that might explain the relationship between sedentary behaviour and weight gain, including lower resting expenditure, displaced opportunities to be physically active, food advertising on TV influencing poorer dietary choices and subsequent energy consumption, and mindless, excessive eating while engaging in screen-time (Robinson et al., 1993). Interventions targeting a reduction in TV and other sedentary behaviours have demonstrated significant reductions in excess weight gain (Must & Tybor, 2005).

Sedentary behaviour guidelines

Developed by CSEP, in partnership with the Healthy Active Living and Obesity Research Group and PartcipACTION, the first evidence-based sedentary behaviour guidelines for children and youth were created to provide recommendations for a) limiting recreational screen-time to no more than 2 hours per day, and b) limiting non-motorized transportation, extended sitting time, and time spent indoors (Tremblay et al., 2011a). Meeting sedentary behaviour guidelines is associated with positive health benefits and outcomes, including improved self-confidence, academic performance, fitness, and maintenance of a healthy body weight (Tremblay et al., 2011a; Tremblay et al., 2011b). However, studies in both Canada and the US have found that youth are not meeting these guidelines, but rather are spending an average of six to eight hours per day, or approximately half of their awake time, in sedentary activities (i.e., screen time) (Garaulet et al., 2011). Data from the 2009 US Youth Risk Behaviour Surveillance identified that 33% of high school students watched more than three hours of television and spent more than three hours on a computer on an average school day (CDC, 2010). The current sedentary behaviour guidelines for youth can be found in Appendix A (Figure 11).

2.4.1.4 Other health behaviours

Substance use behaviours

Several substance use behaviours might be associated with the development of overweight and obesity among youth. As youth transition away from childhood and become increasingly independent, they tend to experiment with health-compromising behaviours. These behaviours might help youth cope with stressful life events, or might be adopted as a function of peer influence. Although only few studies have attempted to identify a relationship between BMI and risky behaviours, a positive association has been found between BMI and smoking initiation (Lowry, Galuska, Fulton, Wechsler, & Kann, 2002), and alcohol, tobacco, and drug use (Pasch, Nelson, Lytle, Moe, & Perry, 2008; Farhat, Iannotti, & Simons-Morton, 2010). Battista and Leatherdale identified that binge drinking youth are at an increased risk of overweight or obesity due to the high caloric values of alcoholic beverages (Battista & Leatherdale, 2017). Aside from this paper, most research on substance use and risky behaviours has focused on their relationship with other health behaviours, and not obesity. For example, a history of binge drinking was inversely related to physical activity in boys, and lifetime marijuana use was positively associated physical activity in boys, while smoking was not associated with physical activity (Kahn et al., 2008). Whether or not they are associated, Leatherdale identified that these risky behaviours tend to co-occur; among 23,280 students in Ontario, 5.5% were current smokers, 22.8% current binge drinkers, and 16.5% current marijuana users (Leatherdale, 2015).

2.4.1.5 Demographic Characteristics

There are some dissimilarities in the prevalence and incidence of BMI across different demographic groups. While overweight and obesity are increasing across the population, (Ogden, Carroll, Kit, & Flegal, 2008), however, the prevalence of overweight (18.3% vs. 13.3%) and obesity (5.8% vs. 3.5%) tends to be higher in boys than in girls (Janssen et al., 2004). Differential rates of overweight and obesity have also been seen among different racial and ethnic groups in the US (Freedman, Kettel Khan, Serdula, Ogden, & Dietz, 2006) and in Canada (Katzmarzyk, 2008), with higher BMI found among non-White students. Among Canadian children and youth aged 2-17 years, the odds of obesity were 2.3 times higher in Aboriginal than non-Aboriginal youth (Katzmarzyk, 2008). This may be explained by genetic differences or cultural practices, or may be associated with factors related to education or economics (Rosenkranz & Dzewaltowski, 2008). Other evidence has suggested that a greater percentage of adolescents from lower socioeconomic status (SES) families experience more obesity (Miech et al., 2006; Janssen, Boyce, Simpson, & Pickett, 2006).

2.4.2 Clustering of health behaviours

Multiple risk behaviours tend to cluster in youth (Driskell, Dyent, Mauriello, Castle, & Sherman, 2008; Alamian & Paradis, 2009). Problem-behaviour theory posits that there might be an underlying behavioural syndrome that drives youth to adopt multiple problem behaviours, which might arise from an imbalance of risk factors relative to protective factors, and may be a combination of individual behavioural and socio-cultural or environmental domains (Jessor & Jessor, 1977). While all of the behaviours discussed in the previous sections are individually associated with overweight and obesity, rarely do they occur in isolation. Instead, their interactions and patterns can have a unique and cumulative effect on the development of overweight and obesity (Leech, McNaughton, & Timperio, 2014), and evidence suggests a link between risky behaviours and obesity, physical activity, diet, and sedentary behaviour (de la Haye, D'Amico, Miles, Ewing, & Tucker, 2014; Lanza, Grella, & Chung, 2014; Leatherdale & Ahmed, 2011). In an effort to reduce overweight and obesity in youth, it is important to understand optimal behavioural patterns associated with a decreased risk of overweight and obesity (Boone et al., 2007).

Cluster analyses – data driven techniques used to identify clusters based on patterns of responses to items on surveys – denote an underlying pattern in health-related behaviours that can be identified through statistical methodologies (McAloney, Graham, Law, & Platt, 2013). Some examples of clustering methodologies include cluster analysis, latent class analysis, factor analysis, and principal component analysis, all of which are designed to identify commonalities across participant responses to items. It is based on these patterns that distinct groups, clusters, or classes are created, to which participants are assigned. These methods focus on observable patterns and co-occurrence across behaviours, as well as identify latent, unobservable clusters or classes.

In earlier research, a greater co-occurrence of risk factors was found in the population than had been predicted from probability rules, rates that were identified by dividing observed by expected prevalence of behaviours to calculate a ratio (Ebrahim, Montaner, & Lawlor, 2004). Ratios greater than one represented a higher prevalence of the behaviour combination than expected (McAloney, Graham, Law, & Platt, 2013). Most studies that use such clustering techniques to explore behavioural patterns of obesity suggest that intervention programs must be refined to account for heterogeneous characteristics (Leech, McNaughton, & Timperio, 2014b). For example, Huh and colleagues suggested that a sequential approach to obesity prevention might be a feasible option for population-based health promotion; the sequences would begin with all youth initially engaging in a universal prevention program, followed by a more focused and targeted program, tailored to the behavioural risk patterns (Huh et al., 2011). Cluster methodologies are useful for policy-makers, as they can lead to more

tailored screening and health recommendations. By understanding that particular health behaviours have a propensity to occur together, and that engaging in one behaviour could potentially modify the risk of engaging in others, interventions can be designed to target multiple health behaviours (Baruth, Addy, Wilcox, & Dowda, 2011). Despite this, evidence on the effectiveness of multifactorial lifestyle interventions has been weak (Ebrahim, Montaner, & Lawlor, 2004). Perhaps incorporating subtypes of student behaviours into the design and implementation of obesity prevention programs or policies in schools will increase effectiveness.

Table 10 in Appendix B provides an overview of 31 studies that examined behavioural patterns in children and youth using a variety of clustering methodologies. The majority of the studies reviewed clustering patterns of obesity-related health behaviours, such as physical activity, diet, and sedentary behaviour. Only 13 of the 31 studies explored a relationship between the identified behavioural clusters and BMI. Only one study included measures of alcohol consumption and smoking in its analysis (Landsberg et al., 2010), identifying that the prevalence of obesity was lowest in the behavioural cluster characterized by high activity and medium risk-taking behaviours. Iannotti and Wang's latent class model with three classes best fit their data, and explained "healthful," "unhealthful," and "typical adolescent" behaviours, with clusters differentially associated with overweight and obesity (Iannotti & Wang, 2013). The students in the class described as high physical activity, high fruit and vegetable consumption, low sedentary behaviour, and low consumption of sweets, soft drinks, chips and fries ("healthful") were most likely to be normal weight (Iannotti & Wang, 2013). Kim and colleagues found similar clusters, such as (1) high physical activity/high sedentary behaviour, (2) high physical activity/low sedentary behaviour, (3) low physical activity/low sedentary behaviour, and (4) low physical activity/high sedentary behaviour, and that these latent clusters were associated with obesity (Kim, Barreira, & Kang, 2016). Finally, using confirmatory factor analysis, de la Haye and colleagues explored their data for an underlying health risk latent variable that might explain the covariance of multiple risk behaviours in youth (de la Haye et al., 2014). They found that behaviours could be explained by two distinct but moderately correlated factors: a substance use risk factor and an unhealthy eating and sedentary behaviour factor.

Research on the clustering of obesity-related health behaviours and other risk factors is lacking in the Canadian context. In fact, a recent study examined how different movement behaviours cluster and relate to overweight and obesity (Carson, Faulkner, Sabiston, Tremblay, & Leatherdale, 2015); the authors concluded that "active screenies" and "unhealthiest movers" were more likely to be overweight or obese compared to the "healthiest movers" (Carson et al., 2015). While insightful, this study did not include measures of substance use in the latent class models, despite the co-occurrence of these

behaviours with obesity-related behaviours and their potential association with obesity. Further, this study only controlled for dietary behaviours, rather than including them in the cluster analysis.

Overall, research clustering methodologies to examine the patterns obesity-related behaviours suggest that obesity interventions accounting for the heterogeneity of students might be more effective (Huh et al., 2011). By identifying subtypes of youth with respect to their health and risk behaviours, and by examining the relationship between behaviours and health outcomes, prevention programs can be designed more effectively.

2.4.2.1 Behaviours and BMI trajectories

To date, most of the research on the determinants of overweight and obesity in youth has been cross-sectional (Biddle, Gorely, & Stensel, 2004). As expected, energy-balance related behaviours, including physical inactivity, dietary behaviours, and sedentary behaviour, tend to show the strongest associations (van der Sluis et al., 2010). While important and informative for guiding future research efforts, cross-sectional studies do not provide sufficient evidence to identify the direction of causality between behaviours and weight status (Elgar, Roberts, Moore, & Tudor-Smith, 2005).

Evidence from prospective observational studies has shown that increased physical activity and decreased sedentary behaviour are protective against increases in BMI during childhood and adolescence (Must & Tybor, 2005). While prospective longitudinal data contribute some of the evidence required for causality, it is not sufficient to conclude a causal relationship. Bradford-Hill developed nine criteria that provide epidemiological evidence of causality (Hill, 1965), these include:

1. strength (effect size);
2. consistency (reproducibility – consistent findings with different samples);
3. specificity (specific population at a specific site with no other likely explanation);
4. temporality (effect occurs after the cause);
5. biological gradient (greater exposure leads to greater incidence of an effect);
6. plausibility (a plausible mechanism explaining the cause and effect);
7. coherence (between epidemiological and laboratory findings);
8. experiment; and
9. analogy (effect of similar factors may be considered)

Quantifying behaviour trends and dynamics by measuring effect size, and having a better understanding of how health behaviours contribute to overweight and obesity, can help direct health promotion strategies to target those behaviours most strongly associated with overweight and obesity. Table 11 in Appendix B provides a summary of some of the longitudinal studies that explored youth health behaviours and obesity, most of which concluded that higher caloric intake, lower physical activity, and higher screen time are associated with larger increases in BMI over time (Berkey et al., 2000; Berkey et al., 2003a; Mitchell, Pate, Beets, & Nader, 2013), and that improving these behaviours

can lead to a decrease in BMI (Elgar et al., 2005; Gordon-Larsen et al., 2002). There is disagreement about which behaviours are most predictive of BMI; Boone and colleagues identified that patterns of physical activity in adolescence were not strong predictors of obesity in early adulthood, but that declines in screen-time were associated with lower rates of obesity (Boone et al., 2007). On the other hand, a systematic review of the literature reported that there was insufficient evidence of a relationship between sedentary time and BMI (Chinapaw, Proper, Brug, Van Mechelen, & Singh, 2011). However, these authors only focused on TV; results might change if the authors included more common sedentary activities in which youth participate, such as playing video or computer games, texting, and talking on the phone (Biddle, Gorely, & Marshall, 2009).

It is possible that some of the relationships between physical inactivity, screen time, and dietary behaviours and BMI are mediated by other health behaviours. Falbe and colleagues found that each additional hour of screen-time per day is associated with a higher consumption of unhealthy food and a decreased consumption of fruits and vegetables (Falbe et al., 2014). Recently, researchers identified a steeper BMI trajectory in children with higher consumption of SSBs, lower participation in organized sports, and higher screen time (Koning, Hoekstra, de Jong, Visscher, Seidell, & Renders, 2016). Overall, most prospective studies suggested that increased physical activity, improved dietary quality, and decreased sedentary behaviour might be protective against weight gain. However, some of these studies suffered from methodological limitations, including measurement issues, residual confounding, focusing on single behaviours, or small sample sizes.

2.4.3 Contextual factors associated with overweight and obesity

Historically, interventions have focused on changing individual behaviours through such means as education or behavioural modification strategies (McLeroy et al., 1988; Sallis et al., 2003). Most of these interventions focused on physical activity or nutrition as separate domains, and were limited in their effectiveness at changing behaviours or reducing BMI. This might be explained by the lack of sustainability when targeting individual behaviours. Instead, modifying the environment has the potential to promote and sustain behaviour changes over a longer period of time by making the environment more conducive to healthy behaviours.

The environment can play a significant role in the development of obesity and obesity-related health behaviours (Ferreira, van der Horst, Wendel-Vos, van Lenthe, & Brug, 2006; Giles-Corti et al., 2005; Hill, Wyatt, Reed, & Peters, 2003). Modifying the environment provides equal opportunity and greater potential to improve health behaviours and outcomes for a whole population. As such, researchers have shifted the focus of intervention and prevention strategies to environmental or contextual determinants of obesity-related behaviours (the more proximal factors) that may reduce

obesity (over time) by directly influencing behaviours (sustained change). Interventions, including those at the macro-level in the SEM, such as policies or wide-scale programming (taxation, transportation) often reach the distal outcome of reducing BMI through its effect on mediators and the behaviours along the causal pathway (physical activity, healthy eating, sedentary behaviour). This can be described through a Mediating-Moderating Variable Framework (Figure 2). Note that moderating variables can play a role along the entire causal pathway, and include those variables by which the outcome of an intervention may vary (i.e., SES, grade, gender)

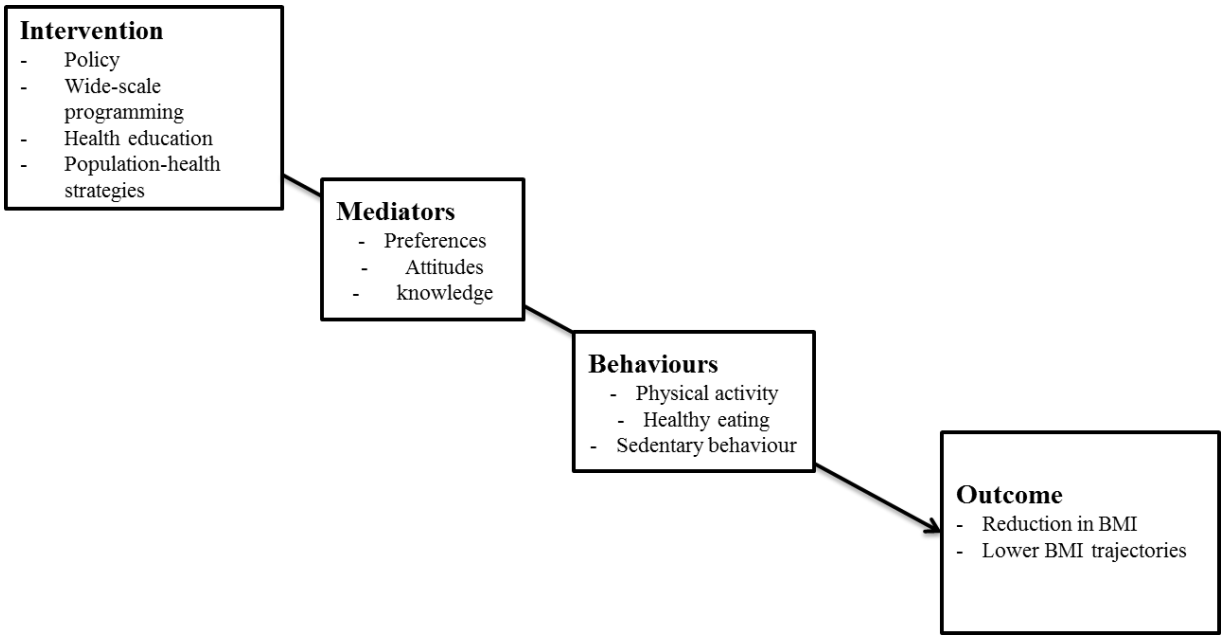

Figure 2. Potential relationship between population-based interventions and BMI.
(Modified from Baranowski, 2009)

A thorough, comprehensive, and systematic model can allow researchers and policy makers to better understand prevention of chronic diseases that can be achieved through environmental and policy approaches (Brownson, Haire-Joshu, & Luke, 2006). For example, a *Population Health Promotion (PHP) Model* (Figure 3) proposed by Hamilton and Bhatti, has been used as a framework for obesity interventions. This model explains the relationship between population health and health promotion through three main components, each making up one-side each of a cube: (1) social determinants of health, (2) comprehensive action strategies, and (3) levels of action.

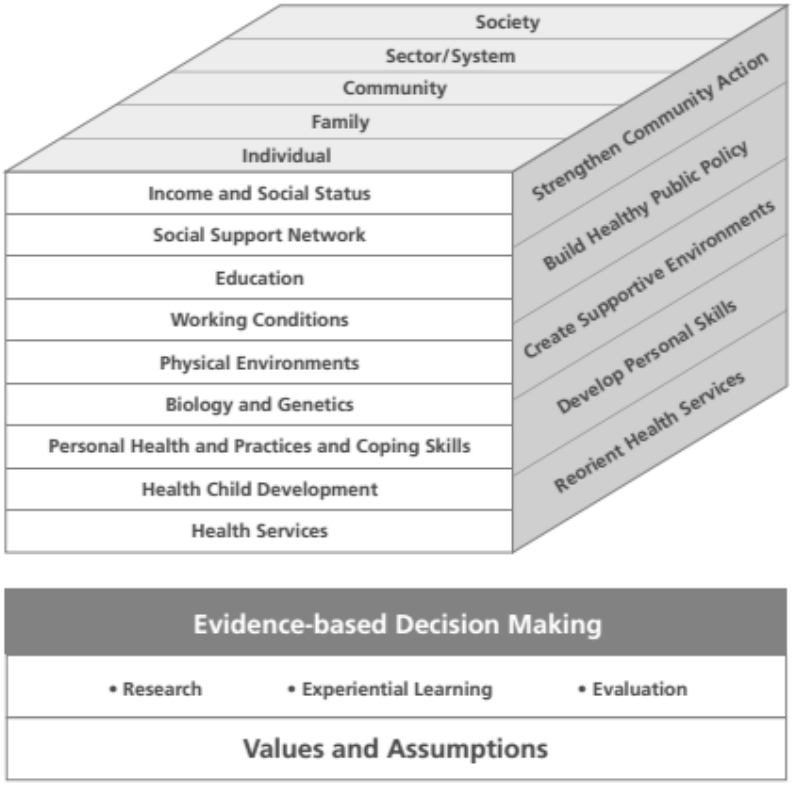

Figure 3. Population Health Promotion Model (Hamilton & Bhatti, 1996)

In addition to applying this PHP in health promotion strategies, the Public Health Agency of Canada (PHAC) emphasizes the importance of evidence to guide action. PHAC recommends that three sources be consulted when assembling the necessary evidence for population-health action:

(1) research studies on health issues, underlying factors, interventions, and their impact (intended or unintended);
(2) experiential knowledge through practice that can be synthesized to guide practice and policy-making; and
(3) formative and summative evaluation of policies and programs.

The PHP Model is easily adaptable to the environments and populations being targeted. For example, schools can create healthier food environments to promote healthy eating, or school boards can develop and implement new policies to increase nutrition education in schools (Larson, Davey, Hoffman, Kubik, & Nanney, 2015) (Figure 4).

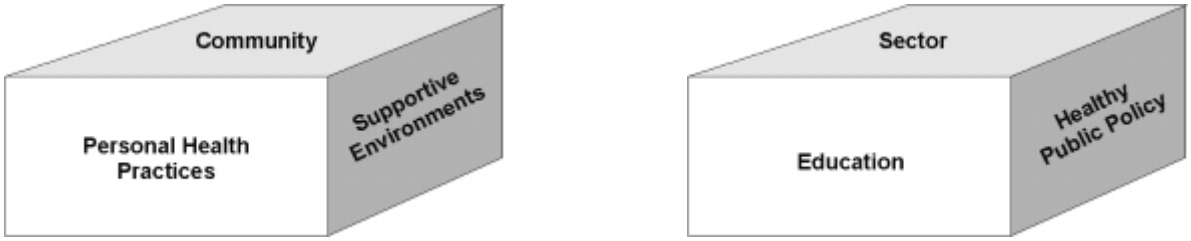

Figure 4. PHP Model example for food environment and policies

2.4.3.1 The school environment

Significant between school variability has been identified for obesity (Leatherdale & Papadakis, 2009; O'Malley, Johnston, Delva, Bachman, & Schulenberg, 2007; Singh, Chinapaw, Brug, & van Mechelen, 2007; Veugelers & Fitzgerald., 2005), physical activity (Leatherdale, Manske, Faulkner, Arbour, & Bredin, 2010; Sallis et al., 2001), sedentary behaviour (Leatherdale, Faulkner, & Arbour-Nicitopoulos, 2010), and other risk behaviours. However, it is not clear which school characteristics are most influential of youth health behaviours (Leatherdale, 2009; Leatherdale & Papadakis, 2009; Naylor, Macdonald, Warburton, Reed, & McKay, 2008). Schools can serve as an ideal setting in which to implement environmental interventions (Jaime & Lock, 2009) since they offer continuous, intensive contact and communication with students, independent of their risk status, and can reach children and adolescents across cultural and socio-demographic backgrounds (Story, Nanney, & Schwartz, 2009). The infrastructure, policies, curricula, and school staff can positively influence youth health behaviours, while programs can be delivered at little-to-no cost, all of which can reach youth that may otherwise not receive any obesity-related prevention programming (Katz, 2009). School programs can capitalize on existing resources and tools to improve student knowledge, skills, and attitudes that are essential to developing healthy lifestyles (Harrison & Jones, 2012). Changes to the school environment can take many forms, including tangible changes through changing food and beverages offered at schools, increasing physical activity during recess periods, improving facilities that support physical activity, increasing physical or nutrition education programs, or through school policies, role modelling, and incentives (Cook-Cottone, Casey, Feeley, & Baran, 2009).

Since schools provide an effective environment in which to intervene (Brown & Summerbell, 2009; De Bourdeaudhuij et al., 2011), international guidelines have been developed for schools to adopt a comprehensive approach to promote healthy behaviours in schools (Story, 1999; Veugelers & Schwartz, 2010). This comprehensive approach, or "Health promoting schools," represents a holistic, whole school approach in which a broad health education curriculum is supported by a healthy school

environment (Allensworth & Kolbe, 1987; Morrison & Kirby, 2010; Veugelers & Schwartz, 2010). By making changes to organizations and policies that align with a healthy school culture and organizational practices, school environments may become more conducive to promoting and adopting healthy behaviours (Lobstein & Swinburn, 2007; Baranowski, Cullen, Nicklas, Thompson, & Baranowski, 2002) that could potentially result in lower rates of obesity (Katz, 2009).

2.4.3.1.1 Comprehensive School Health

There has been a long standing general consensus that schools can exert a strong influence on the health of children and youth (Veugelers & Schwartz, 2010; Cook-Cottone et al., 2009; Katz, 2009). With concerns about fitness, obesity, emotional health, diabetes, violence, and risk behaviours, the health promoting school movement provides a framework for health promotion that targets all youth, rather than just targeting those that exhibit risky behaviours or those at risk of poor health outcomes (Langford, et al., 2011). The World Health Organization's Ottawa Charter for Health Promotion identified a Comprehensive School Health (CSH) approach, a school-based health promotion framework that extends beyond the classroom health education to a more integrated approach that focuses on the whole-school environment (World Health Organization, 1986). CSH has been defined as "an internationally recognized framework for supporting improvements in students' educational outcomes, while addressing health in a planned, integrated, and holistic way" (Veugelers & Schwartz, 2010). There are many synonymous terms for CSH, including "Coordinated School Health" in the US and "Health Promoting Schools" in Canada. Overall, the intention is to create healthier school environments to support the development of healthy behaviours while also working towards improving academic outcomes (Veugelers & Schwartz, 2010).

CSH is made up of four distinct and interrelated pillars: 1) social and physical environment, 2) teaching and learning, 3) healthy school policy, and 4) partnerships and services, all influencing students' overall health and well-being (Morrison & Kirby, 2010). See Figure **5** for an example of a CSH Framework and Table 1 for a more detailed description of the components of CSH. Elements of the CSH Framework would best fit within the macro-level environments and social norms and values of the socio-ecological model, both of which might play a role in shaping overweight and obesity in youth, particularly as they relate to school-based health policies and links with health services and programs (Wang & Steward, 2013).

Figure 5. Comprehensive School Health Framework for supporting improvements in students' educational and health outcomes (http://www.everactive.org/comprehensive-school-health-embedded-wellness)

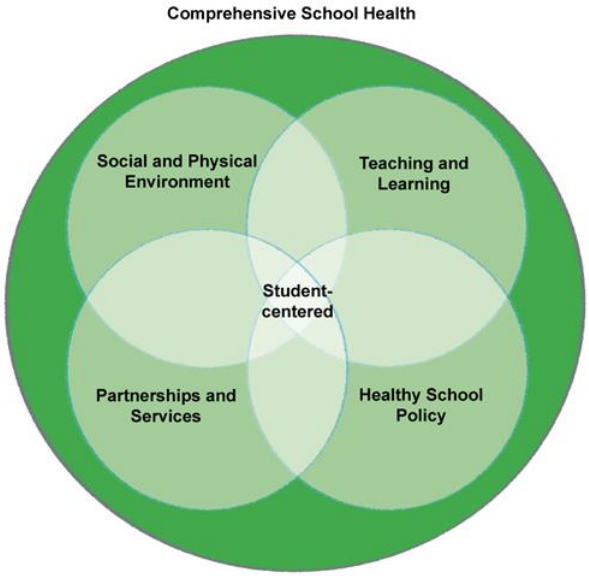

Table 1. Description of the Comprehensive School Health Pillars

Comprehensive school health pillar	Description
Social and physical environment	*Social* environment considers the quality of the relationships among and between staff and students and the emotional well-being of students. A school's social environment may be the barrier to the school community making healthy choices. *Physical environment* is comprised of buildings, grounds, play spaces, and equipment in and surrounding schools, designed to promote health behaviours in a safe and effective way.
Teaching and learning	Includes both student-centered learning and teacher training for students to gain age-appropriate knowledge and experiences to build skills that will improve their health and learning outcomes. School health policies and guidelines can support teachers in taking a CSH approach. *Resources*: school health policies and guidelines.
Partnerships and services	School-community partnerships are integral to the health and well-being of students and surrounding community members. Partnerships enhance the support and opportunities available to students, staff, parents, and wider community. Partnerships include health and education sectors working together, community organizations supporting school activities, donations from a company for lunch programs or community gardens, and contract with fruit and vegetable growers for school fundraising.

Healthy School policy	Management practices, decision-making processes, rules, procedures, policies, and guidelines that promote student wellness and achievement.

Although the CSH framework was developed in response to the *1986 Ottawa Charter*, health promotion in schools to target obesity and its related behaviours increased in importance since 1999 (Story, 1999). Schools are becoming increasingly aware that a comprehensive, "whole school" approach is more effective than educational approaches alone when attempting to modify student health attitudes or behaviours. Schools can play a particularly critical role in obesity prevention by establishing a safe and supportive environment with policies and practices that support healthy behaviours, as well as the opportunities for students to learn about and practice those health behaviours. Until recently, many school-based interventions had focused on students who were overweight or obese, rather than adopting a whole, comprehensive school health approach targeting youth at all levels of risk.

While designed for elementary school-aged youth, an effective CSH intervention – the Alberta Project Promoting active Living and healthy Eating in schools (APPLE schools) – included a full-time school health facilitator in schools to support healthy school environments and healthy behaviours. This approach was successful at improving healthy behaviours, including an increase in fruit and vegetable consumption and improved levels of physical activity (Fung et al., 2012). Students attending APPLE Schools were less obese compared to students attending schools without the CSH intervention. This project is recognized as "best practice" in Canada. While effective programs have been developed for children, less is known about the use of a CSH approach to promote healthier behaviours among high school students.

In response to this need, the CDC has some recommendations for schools to promote physical activity for youth (CDC, 2013), including:

1. providing quality physical education, along with a policy to require daily physical education for students up to grade 12 (225 minutes per week for secondary school students);
2. offering recess
3. providing students with physical activity breaks built into classroom lessons, and enhancing on-task classroom behaviours;
4. offering intramurals – before, during, or after school;
5. offering varsity sports; and
6. walk or bike-to-school programs, which might include creating safer routes to schools and access to secure bicycle racks.

International examples of obesity prevention programs guided by CSH have been conducted in Singapore and Germany. In Singapore, the Trim and Fit Program allowed for nutrition education and physical activity to be incorporated into the school curriculum, along with teacher training, improved

food provision, and weight monitoring. After 10 years, researchers identified a 4% decrease in the prevalence of obesity in students attending those schools (Tob, Chew, & Tan, 2002). In Germany, the Kiel Obesity Prevention Study encouraged students to increase their fruit and vegetable consumption, physical activity, and to decrease time spent watching TV through education and instruction to both parents and youth. This, paired with daily physical activity opportunities and individualized counseling for obese children resulted in improvements to health behaviours and nutrition after only one year (Muller, Asbeck, Mast, Langnase, & Grnd, 2001).

Nutrition policies can be a part of a CSH approach and can help to promote healthy food consumption. In Norway, students provided with low-cost or free fruits and vegetables had healthier diets (Bere & Klepp, 2004). This has been seen among adults in the workplace too – price decreases to low-fat or healthier options may be a powerful approach to improving healthy eating (Pomerleau, Lock, Knai, & McKee, 2005).

Teachers and school administrators who value and show support for obesity prevention are more likely to implement new policies or incorporate aspects of healthy living into the school curriculum (O'Toole, Anderson, Miller, & Guthrie, 2007). Systematic reviews of the literature examining the environmental determinants of physical activity (Ferreira et al., 2007) and dietary behaviours (van der Horst et al., 2007) concluded that the support of the social and family networks were consistently reported. Implementation of policies and ongoing administrative support, role modeling, and environmental cues can help schools support their students' physical activity and food choices (Allensworth, 1997). The implementation of policies related to physical activity and healthy eating demonstrate commitment from school leadership, provide guidance and direction for students, staff, and parents, and can establish accountability for action. Merely changing, adapting, or updating policies can also highlight and focus attention on the importance of the health behaviours.

Public health practitioners can also play a role in promoting a healthier school environment. In 2008, the new Ontario Public Health Standards (Chronic Diseases and Injuries Program Standards) included a mandate that public health professionals are required to work with school boards and schools, "using a comprehensive health promotion approach, to influence the development and implementation of healthy policies, and the creation or enhancement of supportive environments to address the following topics: healthy eating, healthy weights, comprehensive tobacco control, physical activity, alcohol use, and exposure to ultraviolet radiation."[1] Specifically, public health provides valuable sources of support in the community, providing health expertise in areas relevant to the curriculum, immunization, safe-food handling, reproductive and sexual health, substance-use

[1] http://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/docs/ophs_2008.pdf (page 25)

prevention, chronic disease prevention through tobacco control and healthy eating, promotion of physical activity, injury prevention, and control of infectious disease. To help facilitate this process, public health professionals might consider:

- motivating and facilitating involvement of parents, school staff, administrators, and students;
- assisting with the creation and facilitation of school health action teams;
- developing action plans in collaboration with school health action team;
- providing training to teachers, parents, and students about the healthy school framework and the Comprehensive School Health approach;
- building capacity among school community members;
- supporting schools to focus on staff wellness;
- providing opportunities to engage youth, and provide schools with opportunities to influence and support healthy behaviour events in the community;
- assisting in the creation of healthy physical environments within schools (e.g., cafeteria); or
- acting as healthy school coordinators in schools.

2.4.3.2 School Policies and Programs

Policy interventions tend to be broader in design than programs, and are likely to be longer lasting, sustainable, and built into the school culture. Despite the difficulty evaluating school policies and programs, they continue to show promising findings for broad system-level changes (Roseman, Riddell, & Haynes, 2011). Policy and programs can be slotted into the two outermost concentric circles in the SEM, social norms and values and the macro-level/organizational levels, and two of the pillars in the CSH framework (the social/physical environment and healthy school policy) to lead to improvements in student health. For example, policies aimed at tobacco use, through taxation, labelling, and restricting access to youth, were aimed at altering the environment in which choices about tobacco use or non-use are made (CDC, 2000). These policies have formed the basis for other public health initiatives, and may lead the way for obesity prevention. Making systemic changes within schools through policies and programs may modify social norms, creating optimal defaults for youth so that they always engage in healthy behaviours.

In a systematic review of school-based interventions to promote both physical activity and healthy eating in Europe, researchers concluded that combining educational and environmental components that focus on both physical activity and diet are more likely to be effective (De Bourdeaudhuij, 2011). Environmental interventions, such as increasing organized physical activity during school breaks, before, and after school, improving physical activity opportunities within and around school, increasing physical education classes, increasing availability and accessibility to healthy food, and restricting availability or accessibility to unhealthy food, have shown some effectiveness (Doak, Visscher, Renders, & Seidell, 2005; World Health Organization, 2008; Gordon-Larsen, McMurray, & Popkin., 2000). In one study, for each weekday that normal weight adolescents

participated in physical education, their odds of becoming overweight in adulthood decreased by 5% (Menschik, Ahmed, Alexander, & Blum, 2008). This was an important finding, since Trudeau and Shephard found that an hour of daily physical activity can be added to school curricula without negatively affecting academic achievement in other subjects (Trudeau & Shephard, 2008). Further, more comprehensive school wellness policies, including domains related to physical activity policies, competitive foods sold within schools, nutrition practices, and nutrition education, are associated with lower odds and prevalence of overweight and obesity (Coffield, Metos, Utz, & Waitzman, 2011).

In 2009, researchers developed a definition for "obesity policy research," as "the application of quantitative and qualitative research methods, to understand policy-related determinants of obesity and its population level health and economic consequences, and inform policy-based strategies intended to modify obesity's prevalence and trends" (McKinnon et al., 2009). However, little is known about the absolute or relative effects of policy and program changes on overweight and obesity among youth in schools, or the ways in which school policies or programs can alter BMI trajectories. Research is needed to examine and quantify the impact of policies and programs specifically as they relate to physical activity and health eating, and to evaluate newly implemented or modified programs and policies.

There seems to be international support for changing school policies for the purpose of obesity prevention and overall health promotion (Durant et al., 2009; Kubik, Lytle, & Story, 2005; Katz, 2009; Jaime & Lock, 2009; Brown & Summerbell, 2009). School policies dictate the types of resources, incentives, and environments to be made available for physical activity and healthy eating, especially when developed as official statements from education agencies and other governing bodies (e.g. school board, Ministry of Education in Ontario) that may be applied at the provincial, municipal, or school level. School-specific policies can also help to identify actions that schools should take, their purpose, and who is responsible (Bogden, 2000). A review of reviews and meta-analyses to assess the effectiveness of interventions to prevent obesity in children under the age of 19 years concluded that obesity prevention interventions tended to have a modest effect on anthropometric outcomes, especially among those under the age of 12 years (Cauchi, Glonti, Petticrew, & Knai, 2016) (Public Health Ontario, 2013). Small effects, from a population-level perspective, can still be meaningful and important (Rose, 2008); by exposing all students to an effective health promotion intervention, the overall risk of overweight and obesity will decrease, thus leading to population health improvements (Weschsler, Devereaux, Davis, & Collins, 2000). Some interventions have included modifications to the school food environment, the classroom curriculum, and increasing time for physical activity during the school day (Story et al., 2009). However, since obesity-related interventions are considerably heterogeneous in terms of the populations studied, types of interventions, and outcomes measured, it

has been challenging to review or summarize their results to make broad and reaching recommendations. Despite this heterogeneity, a common element across effective interventions has been that they follow a more Comprehensive approach, and are multi-component (Foster et al., 2008), addressing both physical activity and nutrition (Public Health Ontario, 2013; Katz, 2009).

In Ontario, there are two policies embedded in the school curriculum that are designed to promote health behaviours associated with overweight and obesity:

1. *Daily Physical Activity (DPA) for elementary schools*: all elementary school students, including those with special education needs, must have a minimum of 20 minutes of sustained moderate-to-vigorous physical activity each day at school during instructional time. DPA was created to enable elementary school students to improve or maintain their physical fitness and overall health and wellness while enhancing their learning opportunities. School boards are responsible for monitoring DPA.
2. *School Food and Beverage Policy*: nutrition standards for all publicly funded schools that include system-wide requirements for the sale of food and beverages in Ontario schools. This applies to all food and beverages sold on school premises for school purposes in all venues and programs and at all events. Schools are allowed up to 10 days during the school year as special event days on which food/beverages sold in schools are exempt from nutrition standards.

Neither policy has undergone a full-scale evaluation. However, the existence of these policies suggests the potential role that school policies can play in influencing student health behaviours.

To evaluate the effectiveness of obesity prevention interventions, researchers mostly focus on the targeted outcome of interest – BMI or prevalence of overweight and obesity – but sometimes focus on the more proximal measures of health behaviours (Jaime & Lock, 2009; Nanney et al., 2010; O'Malley, Johnston, Delva, & Terry-McElrath, 2009). Interventions have mostly shown only weak associations with BMI (Kropski, Keckley, & Jensen, 2008; Stice, Shaw, & Marti, 2006; Story, 1999), can potentially more easily affect the proximal behaviours. Nanney and colleagues found that each additional recommended obesity-related policy was associated with a decrease in sugar-sweetened beverage consumption and increase in fruit and vegetable consumption (Nanney et al., 2010). Minimal changes in BMI or other anthropometric outcomes do not necessarily suggest that a program or policy was not effective, rather there might have been insufficient data to evaluate effectiveness, or a mismatch between interventions and the contexts in which they were implemented (Evans-Whipp et al., 2004; Ramanathan, Allison, Faulkner, & Dwyer, 2008).

2.4.3.2.1 School Physical Activity Environment

Opportunities for children and youth to be physically active are often tied to the school setting, through daily physical education programming or school-based programs to promote physical activity. Most review studies on physical activity interventions within the school setting report little-to-no

evidence on their effectiveness on anthropometric outcomes, but have found improvements to physical activity behaviours (Morton, Atkin, Corder, Suhrcke, & van Sluijs, 2015; Dobbins, De Corby, Robeson, Husson, & Trillis, 2009; Public Health Ontario, 2013; Katz, 2009). It may be that physical activity interventions require a multi-component approach (Hunter, Leatherdale, Storey, & Carson, 2016), with a component on sedentary behaviour (Safron, Cislak, Gaspar, & Luszczynska, 2011) to have any impact on student BMI. While one study identified that variations in physical activity policies across schools were not sufficient to produce discernible school-wide differences (O'Malley et al, 2009), results may have differed with longer duration and longer follow-up (Gonzalez-Suarez, Worley, Grimmer-Somers, & Dones, 2009). In fact, students attending schools with physical activity policies were found to be more compliant to physical activity guidelines when the school had a written policy in addition to access to facilities for extracurricular activities (Haug, 2010). Conversely, schools with low levels of physical activity policy implementation had a higher proportion (67%) of physical activity guideline non-compliant students (Galan et al., 2014). Although primarily measured in elementary schools and in the US, just over half of schools reported having a policy to provide daily physical education classes to students. However, most of these schools were non-compliant to the policy, and instead, the average time allotted to physical education ranged from 40 minutes for junior elementary students to 75 minutes for senior secondary school students per week (Story et al., 2009).

Physical education classes rarely provide students with adequate time to achieve physical activity recommendations (Trudeau & Shephard, 2008). Extracurricular activities can supplement physical activity for students enrolled in formal physical education classes, but might also serve as the only physical activity opportunity for some students (Wechsler et al., 2000). Extracurricular activities include comprehensive programs that offer physical activity opportunities through competitive and non-competitive sport, fundraising activities, and active recess (Morton et al., 2015; World Health Organization, 2008). Active transportation is another mode by which youth can increase their physical activity levels (Faulkner et al., 2009); policies promoting safe walking and cycling to schools can be implemented by offering students bike racks and safe walking or cycling trails (World Health Organization, 2008). Finally, students can increase activity levels through intramural programs (Ross, Dotson, Gilbert, & Katz, 1985), which might offer more opportunities to increase physical activity than varsity sports, although students that participate in varsity sports tend to have a lower risk of being overweight (O'Malley et al., 2009). Intramural programs give students with less sports experience and skills an opportunity to participate in a wide range of activities, with emphasis on participation and enjoyment, rather than competition (Wechsler, 2000). Such programs, in addition to physical activity

breaks throughout the school day, may help to address overweight and obesity among students (Hood, Colabianchi, McElrath, O'Malley, & Johnston, 2014).

The Ontario Ministry of Education has one policy and one program designed for all publicly funded schools. Although the policy mandating daily physical activity is only for elementary school students, it demonstrates efforts and the feasibility of implementing such policies during the school day.

1. *Daily physical activity in elementary schools, grades 1-8* (described earlier)
2. *Raise the bar*[2] is a program funded by the Ministry of Education, designed to increase physical activity levels for all students through inclusive programming. The Ministry's website offers templates for program ideas to increase participation in physical activities that are inclusive, fun, and rewarding for students.

2.4.3.2.2 School Food Environment

Since youth consume between 35 and 47% of their daily calories during the school day (Briefel et al., 2009), schools are proposed as an important setting to improve student eating behaviours and reduce overweight and obesity. This can be achieved through modifications to the food environments, nutrition-related policies, and supportive programming (Fox, Dodd, Wilson, & Gleason, 2009; McKenna, 2010; Kubik et al., 2003). Some modifiable factors within the school environment include a lack of compliance with nutrition standards for breakfast and lunch programs, or easy access to foods with minimal nutritional quality both within and surrounding schools. Instead of public health or education interventions that target individual dietary behaviour change, food and nutrition policies within schools that change the environment can provide opportunities for healthier food choices for the entire student population (Jaime & Lock, 2009). Such policies exist worldwide and have been shared broadly from the World Health Organization and the CDC (Jaime and Locke, 2009).

The evidence on the influence of school competitive food and beverage policies on student dietary behaviours or BMI is mixed (Chriqui, Pickel & Story, 2014). In a review by Chriqui and colleagues examining the influence of school food and beverage policies on BMI and other weight outcomes, only one study resulted in reduced odds of overweight and obesity (Chriqui et al., 2014; Coffield et al., 2011). Overall, they found that "on the books," or more concrete policies, are achieving their intended goals of reducing in-school availability and subsequent consumption of unhealthy competitive foods and beverages. This is of particular importance for secondary schools, where policies and their enforcement tend to be the weakest (Chriqui et al., 2013). The authors did not consider

[2] http://www.raisethebarintramurals.com/

policies implemented within schools, and were unable to disentangle the federally mandated policies reviewed from those considered "policies in practice," that administrators, school staff, and students might believe to be more important and therefore would be more likely to follow. This was because they feared that such policies, measured through self-reported methods, might be subject to respondent-related bias.

Jaime and Lock (2009) reviewed the effectiveness of school food and nutrition policies worldwide on improving school food environments, student dietary intake, and decreasing overweight and obesity. They defined nutrition guidelines as standards for menu planning based on food and/or nutrients, applied to school meal programs and meals sold in the school environment. Regulation of food and beverage availability was defined as restricting nutrition policies to limit access to unhealthy foods by controlling the type of food and beverages sold and provided in schools. Finally, price interventions included free or subsidized provision of specific foods, or controlling the price of food or beverages for sale to students. It seemed that modifying school policies changed the environment to improve opportunities for access to healthier food choices for the entire student population (Jaime & Lock, 2009). In another study, students attending schools with stricter nutrition policies reported consuming fewer sugar-sweetened beverages and lower rates of overweight and obesity (Masse et al., 2014), especially when exposed to a multicomponent, School Nutrition Policy Initiative (Foster, et al., 2008). It is important to note, however, that students exposed to the multicomponent intervention and those not exposed were both eligible for free and reduced-priced school meals, and were therefore only exposed to the food provided to them by the school.

Most of the research on school programs related to healthy eating has been done in the US and therefore might be difficult to contextualize to Canadian schools. A major difference between Canada and the US is the presence of federally funded meal programs in the US, and the absence of government funding for similar types of nutrition programs in Canada. These federally funded meal programs provide an opportunity to restrict or control the foods that students are exposed to (Winson, 2008). The National School Breakfast and Lunch Programs (NSLP) were created to "safeguard the health and well-being of the nation's children" (Story et al., 2009). More than 30 million youth participate in the NSLP daily, offering an opportunity through which to improve student dietary behaviours (Story et al., 2009). The schools that participate in the NSLP were also required to enforce a school wellness policy (SWP) designed to promote student wellness through a) goals for nutrition education, physical activity, and other school-based activities; b) nutrition guidelines for foods available at schools; c) assurance that guidelines for reimbursable meals will not be less restrictive than federal regulations; d) a plan for measuring implementation of the local SWP; and e) involvement of

parents, students, and school food authorities, school board, administrators, and the public. Each school district designed its own SWP; while some policies may have been weaker than others, they were contextually relevant to their settings which increase the likelihood of compliance and effectiveness (Story et al., 2009).

In Ontario, alongside formal government actions are some informal, localized initiatives or programs that are attempting to improve eating in schools. For example, the Ontario Student Nutrition Program (OSNP) is a provincial initiative designed to provide nutritious food to children and youth through grant funding and start-up assistance. The OSNP has been helpful in preparing and advising breakfast and morning meal programs, healthy snack programs, and has been part of the proliferation of farm-to-school programs (https://www.osnp.ca/). Other than this, there are no pan-Canadian or provincial policies (aside from PPM 150), education requirements, or programs relevant to healthy eating, and there is limited research to characterize the school environment (Browning, Laxer, & Janssen, 2013). In one evaluation of 123 secondary schools across Canada in 2009, Browning and colleagues (2013) identified that 77% of schools in Canada offered cooking classes, and only a small minority offered healthy eating education, gardening activities, and field trips to local food retailers.

2.4.3.2.3 Natural Experiments to modify the food and physical activity environments in schools

Researchers face challenges when designing studies to examine the impact of policy and program changes on BMI or health behaviours. Most research has been through observational studies, which provide rich data on correlation or relationships between the school environment and health. Prospective studies, which allow for multiple measurements on subjects and environments, are often biased towards the null since environments rarely change much over time to detect a change in BMI. Cross-sectional studies are limited by a lack of directionality, and the potential bias of self-selection into neighbourhoods or environments. Ideally, researchers would investigate changes to the environment using a randomized controlled trial (RCT), where some youth are randomly allocated to an environment intervention, and others remain in static environments. This type of RCT is not feasible, since environments and policy changes tend to occur in the real-world and on a much larger scale, controlled by government or school boards rather than researchers (Craig, et al., 2012). Policies or programs could be more appropriately evaluated using natural or quasi-experimental methods, where the outcome of interest is compared between populations exposed to newly implemented policies or programs to those that did not receive the same policy or program exposure.

While natural experiments offer a unique opportunity for research and evaluation of programs and policies within schools and other settings, they are often underused in public health research

(Boarnet, Anderson, Day, McMillan, & Alfonzo, 2005; Petticrew et al., 2005). This is unfortunate, since their results offer opportunities to inform future policy and program decisions based on their opportunistic nature. Natural experiments provide the opportunity to examine health outcomes within the context of real-life or real-world situations (Petticrew et al., 2005), and to demonstrate the effectiveness of school-based obesity prevention, helping to justify widespread implementation across schools (Veugelers & Fitzgerald, 2005). Drawing on lessons learned from other complex population health interventions for tobacco cessation that have utilized natural experiments and quasi-experimental methods (Leatherdale, 2009), we can evaluate the potential impact of environmental or policy changes related to obesity prevention in schools.

Allocation of a natural experiment intervention is not done at random; instead, interventions are implemented based on social or political influence (Dunning, 2005), population needs, or driven by specific contexts. Health promotion programs will have little utility if they do not match the context in which they are being implemented. The use of quasi-experimental methods can contribute to the growing need for practice-based evidence for school prevention programming, by explaining what works, for whom, and in what context (Green, 2006; Brownson & Jones, 2009). For example, using quasi-experimental methods, Cradock and colleagues evaluated the effect of implementing a policy to restrict the sale of sugar-sweetened beverages in schools, identifying a significant decrease in consumption coinciding with the policy change, and no change in consumption among students without policy exposure (Cradock et al., 2011). In another quasi-experimental study, Schwartz and colleagues estimated the impact of water jets on standardized BMI, overweight, and obesity in elementary and middle school students in New York City, and found that water fountains were associated with a significant reduction in standardized BMI for both boys and girls, as well as a reduced likelihood of overweight (Schwartz, Leardo, Aneja, & Elbel, 2016). Finally, naturally-occurring changes to school physical activity policy, recreational programming, public health resources, and the physical environment were examined on adolescent physical activity over a one-year period in schools across Ontario and Alberta (Hunter, Leatherdale, Storey, & Carson, 2016). Between 2013/2014 and 2014/2015, 61 of 86 surveyed schools had made changes to their physical activity resources, nine of which significantly changed students' physical activity levels. Four of the nine were associated with increased student MVPA, and included keeping the fitness centre open at lunch, starting an outdoor club, adding bike racks, and offering different intramural/non-competitive sports. These authors concluded that some changes to facilities and recreational programming can be effective at increasing student MVPA over one-year but that other resources, both within and outside, as well as student interests, are important to consider (Hunter, Leatherdale, Storey, & Carson, 2016). The evidence for

such policies and programs can be generated by implementing these types of successful policies into diverse schools to determine if they remain effective; if unsuccessful, the policy or program may have been poorly planned or executed (Rychetnik, Frommer, Hawe, & Shiell, 2002), or ineffective because different schools have different contexts and needs (Ramanathan et al. 2008). Evaluating natural experiments within schools to generate practice-based evidence and support a more widespread implementation of policies and programs within schools (Leatherdale & Cole, 2015) will require longitudinal studies with longer evaluation periods (Jaime & Lock, 2009; Kropski et al., 2008).

2.4.3.3 Neighbourhood-level demographics

There is variation in rates of overweight and obesity by geographic location in Ontario (Ismailov & Leatherdale, 2010). Youth from rural areas and in neighbourhoods with lower SES tend to be more overweight than youth living in urban settings or neighbourhoods with higher SES (Bruner, Lawson, Pickett, Boyce, & Janssen, 2008; Janssen et al., 2006; Plotnikoff, Bercovitz, & Loucaides, 2004; Willms, Tremblay, & Katzmarzyk, 2003). Schools with a higher concentration of students from lower socioeconomic status households are more likely to have a higher proportion of overweight and obesity (O'Malley et al., 2007).

2.4.4 The physical environment

Researchers have identified links between the built environment and both physical activity and dietary behaviours, but there is no conclusive evidence on specific aspects of the built environment that might promote or prevent obesity. The built environment refers to the physical environment surrounding the home, school, and work, and includes the area within which people spend their time. Specifically, the physical activity environment includes man-made infrastructure, such as recreation facilities, play structures in parks or schools, street design for walkability) and natural green space (i.e., open areas, woods, grassy areas), both of which can influence physical activity behaviours. The food environment consists of food retailers (supermarkets, grocery stores, fast food restaurants, full service restaurants, convenience stores, etc.). Although this dissertation does not focus on the built environment, it is important to recognize that these environments have the potential to exert a strong influence on youth health behaviours and BMI.

2.5 Importance of targeting health behaviours in youth and in schools

Adolescence is a unique challenge in health promotion research, characterized as the developmental stage between parent-managed behaviours to increased behavioural autonomy, combined with growth, development, and the establishment of lasting health behaviours that persist

into adulthood (Singh et al., 2008; Srof & Velsor-Friedrich, 2006). Both obesity and lifestyle behaviours tend to become more resistant to modification with age, and therefore, establishing healthy lifestyle behaviours earlier in life should be an important public health priority (Dietz & Gortmaker, 2001). Since the school represents one of the best settings in which to implement a multidimensional strategy to target overweight and obesity (Story, 1999), and the school has an established and stable communication with youth (Flynn et al., 2006), identifying the specific behaviours and the school-level factors that might influence BMI trajectories is fundamental to inform school-based prevention interventions to reach a large proportion of youth in schools.

2.6 Summary and identified gaps

The prevalence of overweight and obesity among youth is high, and is associated with and may be predicted by several behavioural or environmental factors. Current research, mostly cross-sectional, has shown that obesity is caused by an energy imbalance, characterized by low levels of physical activity, poor dietary behaviours, high screen time, and the environments in which youth engage in these behaviours. Most of the reviewed research has concluded that, in order to improve our understanding of the relationship between health behaviours and overweight and obesity in youth, as well as the influence of the school environment on overweight and obesity, large-scale longitudinal studies are needed.

This review of the literature uncovered several gaps, which can be addressed through this dissertation research and other future studies. First, most studies examining clustering or co-occurrence of youth health behaviours and their association with overweight and obesity did not include a comprehensive list of risky health behaviours, rather focused on just obesity-related health behaviours. Second, most research examining the relationship between behaviour and overweight/obesity in youth, or the school environment and youth adiposity has been cross-sectional, complicating efforts to make any causal inferences. And finally, opportunistic evaluations of the impact of modifying school policies and programs related to BMI have not yet been done, but could increase our understanding of the trajectory of BMI in conjunction with or attributable to changes made to school programs and policies.

Given the lack of longitudinal research focusing on multiple risk behaviours in Canada, there is a need for ongoing surveillance, research, and evaluation of youth risk behaviours and the school-level characteristics associated with BMI that are all amenable to modification. There is not enough timely and relevant research to inform decisions for school-based prevention programming (Kiefer et al., 2005). This information is useful for researchers and stakeholders, to have a more detailed understanding of the link between risk behaviours and the school environment in order to inform future

school-based intervention, as well as the insight and evidence needed to target and tailor existing and future prevention initiatives where they are most likely to have an impact.

Schools are expected to provide students with healthy school environments and opportunities to develop healthy behaviours. There is a gap, however, between research that is being done and the type of research needed to inform prevention strategies. Most evidence has been derived from randomized controlled trials, which are not aligned with real-world practice within schools. Further, prevention interventions targeting youth in schools, such as policies, are often not amenable to randomization, so quasi-experimental designs must be used to evaluate natural experiments as interventions are implemented. This can shift overly controlled efficacy research to that which provides evidence of effectiveness in real world interventions (Nutbeam, 2001). While this evidence may not have the strongest internal validity and may not be perfect, it remains relevant for school stakeholders and policy makers (Petticrew et al., 2005; Judd, Frankish, & Moulton, 2001), can be used to identify effective interventions for real world settings (Petticrew et al., 2005), and reflects realities of intervention implementation to solve public health problems.

To date, there is no systematic way to integrate evidence with action in school-based prevention programming, as there is no ongoing monitoring of school and student-level data to evaluate the impact of natural experiments and changes to school policies and programs over time (Ramanathan et al., 2008; Cameron et al., 2006). As programs and policies change in schools, opportunities to generate the real-world evidence required to improve school environments and student health behaviours are often missed (Leatherdale, 2009). Knowing the outcomes from natural experiments will assist policy makers in developing new, or modifying existing policies and programs. Greater effort is then required to systematically disseminate programs and policies in real world settings (Brownson & Jones, 2009). It is not always possible to wait on significant evidence to act on public health problems, and especially not overweight and obesity in youth; instead, emphasis should be on collaborating with the research users, such as school administrators, on implementing interventions that have proven effective in some settings, and on enhancing interventions when appropriate (Caburnay et al., 2001; Brownson & Jones, 2009). The ability to evaluate natural experiments within schools will add valuable insight for informing the development, tailoring, and targeting of obesity prevention initiatives and interventions within schools so that they are contextually relevant and successful (Brownson et al., 2009).

Few studies worldwide, but none in Canada, have followed youth longitudinally to examine multiple predictors of overweight/obesity and their associated health behaviours simultaneously. Longitudinal research is essential to contribute to our understanding of how behaviours and clustering of behaviours contribute to weight trajectories in youth. A more detailed understanding of the patterns,

trajectories, and determinants of these health behaviours and outcomes is important in guiding the development of effective, evidence-based programs and interventions to improve health behaviours and reduce the risk of overweight and obesity in school-aged youth. This proposed dissertation research, using a comprehensive longitudinal study (COMPASS), investigated the effects of patterns of behaviours and modifications to the school environment on youths' BMI. It was my hope that this project could contribute to the literature by providing researchers and school stakeholders with the knowledge they need to develop obesity prevention strategies and interventions among high school youth.

2.7 Study Aims and Objectives

To address the gaps in the literature, I answered the following research questions:

1. How do major modifiable health behaviours cluster with respect to predicting overweight and obesity in the 2012-2013 baseline COMPASS study?

By identifying groups with shared behavioural patterns, I was hoping to highlight areas for future research and potential interventions to target both broad and specific lifestyle factors. I hypothesized that youth would exhibit 3-5 unique patterns of health behaviours, and that youth engaging in healthier behavioural patterns would be at a lower odds of overweight and obesity. Behavioural patterns that I expected include youth that are active, youth that engage in risky substance use behaviours, youth that spend more time using screens, and youth that might be a mix of all three types.

2. How do the health behaviour clusters identified in research question 1 predict BMI trajectories, controlling for baseline demographic characteristics?

By identifying the specific behavioural clusters that predict BMI trajectories, resources and efforts can be more appropriately directed to improve modifiable behaviours and target those groups at greatest risk of overweight and obesity, and those with poorer BMI trajectories. I hypothesized that the BMI trajectories of youth engaging in less healthy behaviours would be steeper than youth with healthier behaviour patterns.

3. Do changes to school-level obesity-related prevention programs and policies have an effect on BMI trajectories in youth, when controlling for the clusters identified in research question 1?

By identifying specific school-based programs or policies in the domains of physical activity or healthy eating that, when newly implemented in schools, might influence BMI trajectories, I will have the information necessary to make recommendations to policy-makers and school stakeholders to improve student health behaviours and BMI trajectories. I hypothesized that school policies and programs related to both physical activity and healthy eating would have an impact on BMI trajectories, potentially protecting youth from becoming overweight and obese.

Chapter 3

Overview of Methods: COMPASS Host Study

3.1 Overview

This section provides an overview of the study designs and procedures for the components of the COMPASS host study (Y_1 and Y_2) that were cleaned and linked to create one main dataset for this study. COMPASS is a longitudinal study (starting in 2012/13), following a cohort of Grades 9 to 12 students attending a convenience sample of Ontario and Alberta secondary schools for four years[3] to understand how changes in the school environment (programs, policies, resources, and built environment) influence the development or change the trajectory of youth health behaviours and outcomes (Leatherdale et al., 2014). COMPASS provides school stakeholders with the evidence required to guide and evaluate school-based interventions related to the health outcomes measured in COMPASS and their correlates (obesity, physical activity, healthy eating, sedentary behaviour, marijuana use, smoking, alcohol use, bullying, school connectedness, and academic achievement). COMPASS was designed to facilitate multiple large-scale school-based data collections, with an in-class, whole-school sampling and data collection method (Leatherdale et al., 2011; Leatherdale & Rynard, 2013).

3.2 Data Sources

This dissertation research focused on Ontario students in grades 9 to 12 and the schools that they attend, collected using the 2012/13 (Y_1), 2013/14 (Y_2), and 2014/15 COMPASS survey (Y_3). Since students are nested within their schools and surrounding environments, COMPASS collects information from several different sources, which are all described in the following sections. Student-level data from COMPASS questionnaire were linked to the school-level data on policies and programs, collected from the SPP.

3.2.1 COMPASS Questionnaire

Student-level data in the COMPASS study are collected using the COMPASS Questionnaire (Cq) (full Cq is included in Appendix C). The Cq is a 12-page machine-readable paper booklet questionnaire that students complete in 35-40 minutes in the classroom. Survey items chosen reflected

[3] COMPASS has been extended by an additional five years

public health trends, as well as science-based (e.g., obesity, tobacco use) and practice-based (e.g., bullying, school connectedness) concerns (Bredin & Leatherdale, 2014).

COMPASS follows an active-information, passive-consent permission protocol (passive consent) to obtain permission from parent(s) or guardian(s) of students in schools that agreed to participate in COMPASS. This protocol involves distributing a letter or an automated phone message to parents that describes the nature of the study, and requests that the parent call or email the research team should they prefer that their child not participate in the study. All students in participating schools whose parents did not contact the research team are eligible to participate. At any point during the consent process or during the data collection, an eligible student can decline to participate or choose to withdraw their questionnaire from the study (Thompson-Haile et al., 2013). Passive consent protocols are less prone to biases, ensure that students are not excluded for whom prevention is most necessary (as often happens when students fear that their responses to controversial questions may be discovered), and collect no personal information from students (unless their parents request non-participation), and therefore, ensure confidentiality (Thompson-Haile et al., 2013).

3.2.1.1 Sampling

Since COMPASS was not designed to be provincially or nationally representative, COMPASS schools were purposefully sampled by contacting school boards that allowed for passive consent procedures. Measures used in the student COMPASS questionnaire (Cq) were consistent with those used in other self-report, school-based studies of youth in Canada (e.g., Canadian Student Tobacco, Alcohol, and Drug Use Survey, the Health Behaviour in School-Aged Children Survey [Roberts et al., 2009]) and in Ontario (e.g., Ontario Student Drug Use and Health Survey). Using similar measures and protocols allows for cross-study comparisons to existing population-based surveys. Preliminary analyses of the COMPASS data and publications from the first year of COMPASS data demonstrate health behaviours and health prevalence rates consistent with those of nationally representative studies (Leatherdale, 2015).

3.2.1.2 Ethics

COMPASS was approved by the University of Waterloo Office of Research Ethics, all participating School Boards and individual schools. All eligible students who were present on the data collection day that were not denied to participate by their parents, and agreed to participate, completed the Cq. Students were allowed to decline participation or to withdraw their survey at any time.

3.2.1.3 Survey Protocols

The Cq was used to measure student health behaviours and related health outcomes. There are 65 questions in total. Two questions were used to identify weight status by calculating body mass index (BMI); one question (seven separate 7 items) was used to measure sedentary behaviour; eight questions were used to assess level and quality of physical activity behaviours; seven questions were used to measure dietary behaviours.

Teachers administered the Cq during a designated class period that was requested by the school, between October 2012 and June 2013, October 2013 and June 2014, and October 2014 and June 2015 for years 1, 2, and 3, respectively. Students completed the questionnaire in approximately 35 to 40 minutes. Teachers were provided with detailed instructions for implementing the survey to ensure consistency, to protect student confidentiality, and to ensure that the process was easy for the teachers. A trained data collector was present at each data collection to oversee the data collection, answer student and/or staff questions and concerns, collect the SPP, and to collect the within-school built environment data (not relevant for this dissertation research). Individual student participants did not receive remuneration for participation; however, schools were given $200 honorarium, a customized *School Feedback Report*, and access to a COMPASS *Knowledge Broker* (section 3.2.3). Additional details on the COMPASS survey protocols are available online (http://compass.uwaterloo.ca) and in print (Leatherdale et al., 2014).

3.2.2 COMPASS School Policies and Practices Questionnaire

The COMPASS School Policies and Practices Questionnaire (SPP) is a paper-based survey that is completed by the COMPASS school contact most knowledgeable about the programs and policies offered at the school. In most cases, this contact was the school administrator, a guidance counselor, or a student success teacher. The SPP was designed similarly to the validated Healthy School Planner tool (Leatherdale, Manske, Wong, & Cameron, 2009), but was shortened and tailored to measure school environment factors relevant to the health behaviours and outcomes measured in COMPASS. The SPP was designed to collect information on the presence or absence of programs, policies, resources, and facilities, as well as changes to (adding/removing) programs, policies, resources or facilities that might be related to the health behaviours or outcomes measured in the Cq. Completed SPPs are collected from the school on the data collection day, along with copies of policy handbook(s) and/or student agenda. SPP information has been further supplemented by school and school board website scans for additional details and/or other relevant school policies related to the COMPASS health behaviours and outcomes that are not listed in the student handbook and/or overlooked by the school administrator. The

SPP was modified for COMPASS year 2 and subsequent data collections – to best capture changes made to school policies, programs, and resources, schools were provided with their baseline (year 1) SPP responses in table format, with space to indicate if changes were made, and to include details about the changes. Examples of both SPPs are included in Appendix D.

3.2.3 Knowledge Transfer and Exchange Activities

3.2.3.1 School Feedback Report

Eight to ten weeks after school data collections, each school receives a customized school feedback report, which provides schools with data on their students' health behaviours and outcomes of interest, comparisons to national or provincial norms or guidelines where available, and evidence-based suggestions for interventions, programs, or policy changes to improve student health behaviours (Church & Leatherdale, 2013). The profiles are designed to equip school stakeholders with the information they need to set priorities for taking action and for designing appropriate interventions. The local public health unit and knowledge broker contact are included, should the school wish to seek out support for taking action based on the findings in their profiles.

3.2.3.2 COMPASS Knowledge Broker

COMPASS staff and graduate students work as knowledge brokers with the schools to a) facilitate interaction between the COMPASS team, community partners, and the schools; b) enhance the utility of the school feedback report by making suggestions for school improvement based on the school-specific findings; c) identify and share innovative ideas for health promotion in schools and grant opportunities; and d) collect process measures from interventions implemented as a function of the COMPASS results. The purpose of the knowledge broker is to ensure that the schools are involved in the entire research process, which has been found to be associated with more effective and lasting changes at the school-level, mostly as a function of increased buy-in (Thompson-Haile, Laxer, Ledgley, & Leatherdale, 2015).

3.2.4 Census Data

The most recent National Household Survey data[4] (2011) were used to gather additional environmental data about the neighbourhoods surrounding schools and the neighbourhoods in which youth spend their time. Specifically for this research, only school site (urban/rural status) was included.

[4] http://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/index.cfm?Lang=E

New definitions for the urban-rural continuum were developed for the 2011 census and will be used for this thesis: "Rural" is defined as having a population <1,000, with a density of <400 per square km. A "small population centre" has a population of 1,000 to 29,999; "medium population centres" have populations of between 30,000 and 99,999; "large urban population centres" consist of populations of ≥100,000 (from urban areas to population centres, accessed from http://www.statcan.gc.ca/subjects-sujets/standard-norme/sgc-cgt/notice-avis/sgc-cgt-06-eng.htm on May 13, 2015). Census data were linked to the Cq and SPP data by the school identifier (SchoolID).

3.3 Measures

This section provides an overview of the measures that were used for the response (dependent) variables (3.3.1), student-level predictor/explanatory variables (3.3.2) and the school-level explanatory variables (3.3.3). Operational definitions for the measures used in this dissertation research are consistent with previous research using national standards, and other current national public health guidelines. Using these definitions ensured that this research was consistent with, comparable to, and had the potential to contribute to standards set forth by Canadian public health authorities. These authorities are responsible for determining risk factor measures that are health promoting for youth, and for developing and implementing population-level strategies to improve health behaviours and outcomes.

3.3.1 Response variables

Overweight and Obesity:

The outcome of interest in this dissertation was youths' weight status, using both categorical (normal, overweight/obese) and continuous measures (BMI trajectories)[5]. Self-reported height and weight items used in the Cq were consistent with those used in other population-based youth surveys, including the Youth Risk Behaviour Survey (YRBS) (Brener, Mcmanus, Galuska, Lowry, & Wechsler, 2003), the Youth Smoking Survey (YSS) (Elton-Marshall et al., 2011), and the Health Behaviour in School Aged Children Survey (HBSC) (Currie, Samdal, Boyce, & Smith, 2001), with a slight modification – students were provided with both metric and imperial response options, as well as the opportunity to write their height and weight following "My weight is _____ pounds/kilograms" and "My height is _____ inches/centimeters." Data derived from the height and weight measures on the Cq were used to calculate student body mass index (BMI) (kg/m^2). For a categorical response variable (healthy weight, overweight, and obese), the cutpoints developed by the Childhood Obesity Working

[5] Since ~1.5% of students were classified as underweight, these students were combined with those categorized as normal weight

Group of the International Obesity Task Force were used (Cole, Bellizzi, Flegal, & Dietz, 2000). For a continuous response variable, the BMI value itself was reported; this has been found to be an appropriate way to measure change in adiposity, and similar methods have been used in previous longitudinal studies (see Table 11). The items used in the Cq to measure height and weight have demonstrated substantial test-retest reliability, with intraclass correlations (ICC) ranging from 0.95 to 0.99 and validity ICC ranging from 0.84 to 0.95 (Leatherdale & Laxer, 2013). Students were reminded to measure their height and to weigh themselves the night before their surveys.

Missing obesity data

In an analysis of the modifiable risk behaviours in the baseline COMPASS sample, Leatherdale (2015) identified that 20.3% (2,391) of males and 22.4% (2,572) of females had missing BMI data. This is a known limitation with self-reported height and weight data, and is common in survey research on health behaviours and overweight/obesity. This was considered in the analyses and addressed in the limitations. Since this research was not intended to be representative, students with missing BMI data were excluded. Future research might consider imputing BMI data to identify if missing BMI impacts the results (Hunsberger, Murray, Davis, & Fabsitz, 2001). This was beyond the scope of this dissertation research, and was therefore, not included.

3.3.2 Student-level explanatory variables

3.3.2.1 Behavioural characteristics

The Cq collects behavioural characteristics and sociodemographic factors about students that may explain or predict overweight and obesity. The primary behavioural characteristics considered in this research included physical activity, dietary behaviours, and sedentary behaviour. However, physical activity, diet, and sedentary behaviour are not the only health behaviours established during adolescence that are associated with or impact the development of overweight and obesity. Indeed, other risky health behaviours, including substance use (smoking, drinking, and drug use) tend to be established during adolescence, and are often found clustered within the same individuals (Leatherdale & Rynard, 2013). Other behavioural characteristics identified to be related to obesity and its correlates in the literature review were included as potential predictors of obesity. These student-level characteristics may independently or collectively be associated with overweight/obesity. Detailed information on these behavioural characteristics and sociodemographic correlates are explained below.

Physical Activity:

The Cq physical activity measures were based on previously validated physical activity measures that were used in the School Health Action Planning and Evaluation Systems (SHAPES)

(Leatherdale et al., 2009; Wong, Leatherdale, & Manske, 2006). The Cq measure was updated to provide students with definitions and examples of 'hard' and 'moderate' physical activity ("Hard physical activities include jogging, team sports, fast dancing, jump-rope, and any other physical activities that increase your heart rate and make you breathe hard and sweat. Moderate physical activities include lower intensity activities such as walking, biking to school, and recreational swimming."). Test-retest reliability and validity of the measures were sufficient and consistent with other physical activity measures (ICCs ranging from 0.68 to 0.79) (Leatherdale, Laxer, & Faulkner, 2014). Student responses identified whether students were meeting the Canadian Physical Activity Guidelines, as defined by the Canadian Society for Exercise Physiology (specifically 60 minutes of physical activity daily (see Appendix A, Figure 10). Students who indicated that they are physically active for at least 60 minutes per day were considered 'active', or 'meeting physical activity guidelines,' while the remaining students were considered 'inactive,' or 'not meeting physical activity guidelines.'

Additional questions related to physical activity in the Cq included in this dissertation were strength training ('On how many days in the last 7 days do you do exercises to strengthen or tone your muscles?'), participation in intramurals/non-competitive sports clubs ('Do you participate in before-school, noon hour, or after-school physical activities organized by your school'), and varsity sports ('Do you participate in competitive school sports teams that compete against other schools?'). Response options for strength training were as 'yes' if students are performing strength training exercises ≥3 days per week, and 'no' if <3 days per week. Response options for intramural and varsity sports were 'yes' or 'no.'

Healthy Eating

While there are existing tools and gold standards to measure dietary behaviours, such as 7-day dietary food recalls or food diaries, they tend to be too time-consuming and intensive, and would not be suitable for the COMPASS protocol. Instead, the Cq dietary measures were simple, and were aligned and specific to Canada's Food Guide (See Appendix A, Figure 12). These questions produced both reliable and valid estimates of youth consumption patterns specific to the components of Canada's Food Guide – vegetables and fruit, grain products, milk and alternatives, meat and alternatives (Leatherdale & Laxer, 2013). This is the first time that measures specific to Canada's Food Guide have been used to measure dietary behaviours among youth, and COMPASS was granted permission to use images and wording directly from Canada's Food Guide. While COMPASS measures the proportion of students within the sample that are meeting each and all four of Canada's Food Guide recommendations, only fruit and vegetable consumption was considered as a predictor of overweight and obesity, since meeting recommendations for fruit and vegetable consumption is most closely

associated with reduced risk of chronic disease in youth, over the other three recommendations. The Cq test-retest reliability of fruit and vegetable consumption was 0.68, while the concurrent validity was 0.53. Additional details about the reliability and validity of the dietary intake measures can be found in (Leatherdale & Laxer 2013). While the fruit and vegetable recommendations for males and females are 8 and 7 servings/day respectively, consistent with previous research and recommendations from the CDC, students consuming ≤5 servings of fruits and vegetables per day were classified as not meeting guidelines/consuming inadequate fruit and vegetables. Questions that measured whether or not students met the recommendations were worded as: 'Yesterday, from the time you woke up until the time you went to bed, how many servings of…did you eat? a) meat and alternatives, b) vegetables and fruit, c) milk and alternatives, and d) grain products'

Additional diet-related questions on the Cq relevant for this dissertation covered issues such as: breakfast consumption (# of days that students eat breakfast), snacking at school (# days that students purchase snacks from a corner stores), sugar-sweetened beverage consumption (# of days that students drink soda pop, Kool-Aid, Gatorade, etc.), and fast food consumption (# of days).

Sedentary Behaviour

Sedentary behaviours were measured using a validated measure of self-reported sedentary behaviours appropriate for use in a large population based survey (Leatherdale et al., 2014), modified from those used in SHAPES research (Leatherdale & Ahmed, 2011; Wong & Leatherdale, 2009). The COMPASS measures of sedentary behaviour were adapted to include examples on how to complete the questions (i.e., 'for example, if you spend about 3 hours watching TV each day, you will need to fill in the 3 hour circle, and the 0 minute circle as shown below'), included additional and more relevant categories of sedentary behaviour that are consistent with changing media and youth interests (e.g., streaming TV shows/movies), and provided additional response categories for students to respond in 15 minute increments. Refer to Appendix A, Figure 11 for the Sedentary Behaviour Guidelines.

Activities considered to be sedentary in the COMPASS questionnaire are: "watching/streaming TV shows or movies," "playing video/computer games," "doing homework," "talking on the phone," "surfing the internet," "texting, messaging, emailing; (note: 50 texts = 30 minutes)," and "sleeping." For the purpose of this dissertation research, I defined sedentary behaviours as those behaviours that are "screen-based" or "not productive," which include television/movies, video/computer games, talking on the phone, surfing the Internet, and texting/messaging/emailing. Youth that report spending ≥2 hours in screen-based sedentary behaviours were considered "not meeting sedentary behaviour guidelines," or "highly sedentary," while youth reporting <2 hours in screen-based sedentary behaviour will be considered as "meeting sedentary behaviour guidelines" or "low sedentary."

The average time that youth spend doing homework and sleeping were not included in the total sedentary behaviour time, since they are considered productive and necessary for healthy development rather than recreational (Leatherdale & Harvey, 2015).

Other Risk Behaviours

Other behavioural characteristics that were investigated in this dissertation included smoking, marijuana use, and binge drinking. *Smoking status*: students reporting ever smoking 100 cigarettes or smoking in the previous 30 days were classified as *smokers* (Wong et al., 2012). C*urrent binge drinkers* included students that reported consuming five or more drinks of alcohol on one occasion at a frequency of ≥1 time per month (Herciu et al., 2014). Finally, *current marijuana users* included those that reported marijuana use ≥1 time per month.

3.3.2.2 Sociodemographic Characteristics

Sociodemographic correlates of interest included Grade (9, 10, 11, 12), gender (male, female), ethnicity (categories collapsed and recoded into White, Off-Reserve Aboriginal, and Other) and weekly spending money. Grade was selected rather than age, because the end-users of the results of this research would benefit from the results presented by grade. Information on weekly spending money was obtained by asking respondents to report how much money they get each week to spend on themselves or to save (categories recoded to $0, $1 to $20, $21 to $100, more than $100, I don't know).

3.3.3 School-level explanatory variables

3.3.3.1 Demographics

Information on school site/geographic location (large urban, medium urban, small urban, and rural) was determined using the 2011 census data for the communities surrounding sampled schools, based on school postal codes (Reitsma & Manske, 2004).

3.3.3.2 School-level policies and programs

School-level policies, programs, and resources related to overweight/obesity and associated health behaviours (physical activity, dietary behaviours, and sedentary behaviour) were identified from responses to the School Policies and Practices Questionnaire (SPP). School environment factors of interest included:

- Policies related to physical activity or healthy eating
- School participation in healthy eating or nutrition programs:
    - School breakfast program
    - Cooking classes

    - Gardening
    - Field trips to farmers markets/grocery stores
- Participation of the school in physical activity programs
    - Intramurals
    - Varsity sports
    - Special events
- Access to indoor or outdoor physical activity areas or equipment during non-instructional time

This information was collected and compared across the first two years for all of the COMPASS schools.

Chapter 4
Manuscript 1: Clustering of risk-related modifiable behaviours and their association with overweight and obesity among a large sample of youth in the COMPASS study

Manuscript published in BMC Public Health

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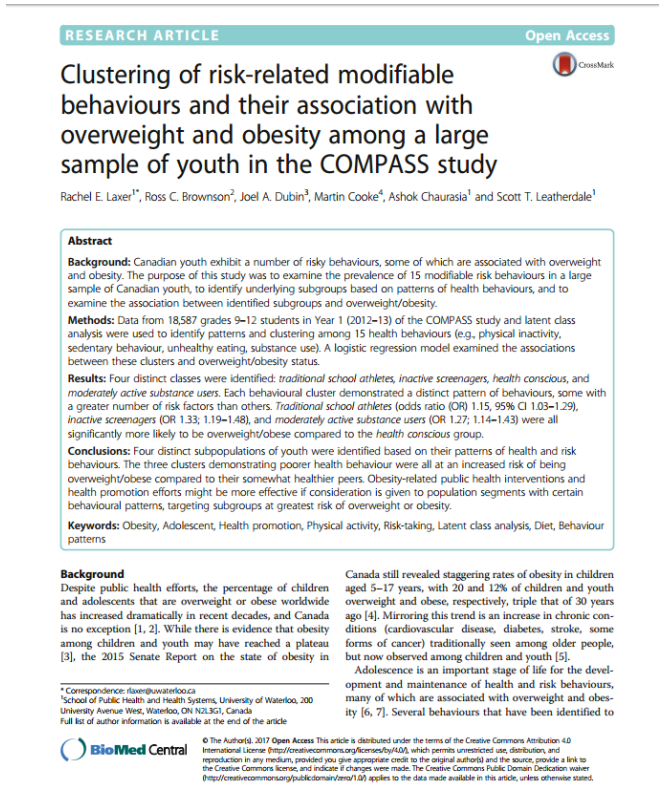

RESEARCH ARTICLE Open Access

Clustering of risk-related modifiable behaviours and their association with overweight and obesity among a large sample of youth in the COMPASS study

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Abstract

Background: Canadian youth exhibit a number of risky behaviours, some of which are associated with overweight and obesity. The purpose of this study was to examine the prevalence of 15 modifiable risk behaviours in a large sample of Canadian youth, to identify underlying subgroups based on patterns of health behaviours, and to examine the association between identified subgroups and overweight/obesity.

Methods: Data from 18,587 grades 9–12 students in Year 1 (2012–13) of the COMPASS study and latent class analysis were used to identify patterns and clustering among 15 health behaviours (e.g., physical inactivity, sedentary behaviour, unhealthy eating, substance use). A logistic regression model examined the associations between these clusters and overweight/obesity status.

Results: Four distinct classes were identified: *traditional school athletes, inactive screenagers, health conscious*, and *moderately active substance users*. Each behavioural cluster demonstrated a distinct pattern of behaviours, some with a greater number of risk factors than others. *Traditional school athletes* (odds ratio (OR) 1.15, 95% CI 1.03–1.29), *inactive screenagers* (OR 1.33; 1.19–1.48), and *moderately active substance users* (OR 1.27; 1.14–1.43) were all significantly more likely to be overweight/obese compared to the *health conscious* group.

Conclusions: Four distinct subpopulations of youth were identified based on their patterns of health and risk behaviours. The three clusters demonstrating poorer health behaviour were all at an increased risk of being overweight/obese compared to their somewhat healthier peers. Obesity-related public health interventions and health promotion efforts might be more effective if consideration is given to population segments with certain behavioural patterns, targeting subgroups at greatest risk of overweight or obesity.

Keywords: Obesity, Adolescent, Health promotion, Physical activity, Risk-taking, Latent class analysis, Diet, Behaviour patterns

Background

Despite public health efforts, the percentage of children and adolescents that are overweight or obese worldwide has increased dramatically in recent decades, and Canada is no exception [1, 2]. While there is evidence that obesity among children and youth may have reached a plateau [3], the 2015 Senate Report on the state of obesity in Canada still revealed staggering rates of obesity in children aged 5–17 years, with 20 and 12% of children and youth overweight and obese, respectively, triple that of 30 years ago [4]. Mirroring this trend is an increase in chronic conditions (cardiovascular disease, diabetes, stroke, some forms of cancer) traditionally seen among older people, but now observed among children and youth [5].

Adolescence is an important stage of life for the development and maintenance of health and risk behaviours, many of which are associated with overweight and obesity [6, 7]. Several behaviours that have been identified to

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Brief Overview and Purpose

This manuscript is presented as it was published in BMC Public Health. Supplementary material for this manuscript can be found in Appendix E.

Measuring how health behaviours cluster instead of only examining their co-occurrence offers a number of advantages, such as identifying underlying patterns of associations between behavioural patterns, rather than just examining how and which behaviours co-occur. This manuscript explored how 15 modifiable risky behaviours cluster together, and how behavioural clusters were related to overweight and obesity in COMPASS youth.

Outline

Background: Canadian youth exhibit a number of risky behaviours, some of which are associated with overweight and obesity. The purpose of this study was to examine the prevalence of 15 modifiable risk behaviours in a large sample of Canadian youth, to identify underlying subgroups based on patterns of health behaviours, and to examine the association between identified subgroups and overweight/obesity.

Methods: Data from 18,587 grades 9–12 students in Year 1 (2012-13) of the COMPASS study and latent class analysis were used to identify patterns and clustering among 15 risk behaviours (e.g., physical inactivity, sedentary behaviour, unhealthy eating, substance use). A logistic regression model examined the associations between these clusters and overweight/obesity status.

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Conclusions: Four distinct subpopulations of youth were identified based on their patterns of health and risk behaviours. The three clusters demonstrating poorer health behaviour were all at an increased risk of being overweight/obese compared to their somewhat healthier peers. Obesity-related public health interventions and health promotion efforts might be more effective if consideration is given to population segments with certain behavioural patterns, targeting subgroups at greatest risk of overweight or obesity.

Key words: obesity, adolescent, health promotion, physical activity, risk-taking, latent class analysis, diet, behaviour patterns

Introduction

Despite public health efforts, the percentage of children and adolescents that are overweight or obese worldwide has increased dramatically in recent decades, and Canada is no exception [1,2]. While there is evidence that obesity among children and youth may have reached a plateau [3], the 2015 Senate Report on the state of obesity in Canada still revealed staggering rates of obesity in children aged 5-17 years, with 20% and 12% of children and youth overweight and obese, respectively, triple that of thirty years ago [4]. Mirroring this trend is an increase in chronic conditions such as cardiovascular disease, diabetes, stroke, and some forms of cancer, traditionally seen among older people, but now observed among children and youth [5].

Adolescence is an important stage of life for the development and maintenance of health and risk behaviours, many of which are associated with overweight and obesity [6,7]. Indeed, several behaviours that have been identified to contribute to increased morbidity and mortality, such as physical inactivity, poor diet, and alcohol, drug, and tobacco use [8] are common among Canadian youth and tend to increase with age [9]. These behaviours do not occur in isolation; rather, evidence suggests that adolescents adopt patterns of healthy or risk behaviours [10] that collectively contribute to poor health outcomes, including overweight and obesity [11,12]. This is concerning, given that two or more risky health behaviours can amplify the risk of developing chronic diseases [13] and that most youth prevention initiatives are specific to single risk factors (e.g., tobacco control) [14].

While the focus of obesity prevention has shifted from individual to population-level approaches [15] with the intention of reaching individuals at all levels of risk and reducing risk of stigmatization, such broad-based solutions may not be appropriate or effective for all youth [16]. Indeed, there are individual differences in behaviours that are often overlooked in such broad-based interventions [17], which might influence their effectiveness. For example, the majority of school-based obesity prevention programs target two specific sets of health behaviours that are related to obesity – physical activity and dietary behaviours – rarely considering other co-occurring or related health behaviours [18,19]. More recently, researchers have begun to explore connections between various health behaviours using clustering or latent class analysis, an analytic method that groups heterogeneous populations based on homogeneous characteristics. While these studies have identified behavioural clusters based on patterns of substance use [20], smoking [21], dietary behaviours [22], physical activity patterns [11], or other lifestyle characteristics [23], only few have attempted to draw an association with overweight or obesity [11,24]. Despite this, all extant studies have confirmed the importance of developing targeted interventions [25], refined to account for heterogeneous

characteristics of youth, a population known to exhibit and sometimes adopt a large number of risky behaviours.

The purpose of this study was to (1) examine the prevalence of modifiable risk behaviours in a large sample of Canadian youth, (2) identify homogeneous classes of adolescents based on their obesity-related health and substance use behaviours, and (3) examine how the behavioural classes are associated with overweight/obesity. Identifying the heterogeneity in youth health behaviour patterns might improve both the reach and effectiveness of obesity-related interventions by tailoring programs to those that exhibit behaviours associated with a greater risk of obesity.

Methods

Design

COMPASS is a prospective cohort study designed to collect longitudinal data from a sample of secondary school students and the schools that they attend in Ontario and Alberta, Canada [26]. This paper reports on cross-sectional findings from the baseline (Year 1; 2012-13) data collection from 43 purposefully sampled Ontario schools that agreed to use active-information passive-consent parental permission protocols [27]. All student-level data were collected using the COMPASS questionnaire (Cq). A full description of the COMPASS study and its methods is available online (www.compass.uwaterloo.ca) and in print [26]. The COMPASS study received ethics approval from the University of Waterloo's Office of Research Ethics, as well as participating school board review panels.

Measures

Health and Risk Behaviours

Behavioural indicators were selected to represent both theoretically and clinically relevant behaviours associated with overweight and obesity.

Physical activity. Four items were used to assess physical activity behaviours. Students recorded (1) time spent in hard (i.e., jogging, team sports) and moderate (i.e., walking, biking to school) physical activity on each of the previous seven days. Minutes were averaged, and responses were dichotomized to "less than 60 minutes per day" and "more than 60 minutes per day" to match one component of Canada's Physical Activity Guidelines for Children and Youth [28]. Students also indicated whether they had participated in (2) physical activities organized by the school (e.g., intramurals, non-competitive clubs) or (3) competitive school sports teams (e.g., junior varsity or varsity sports). For both, students were dichotomized into "participating" or "not participating" in intramurals or varsity

sports. Students were asked to record (4) the number of days in the previous week they had engaged in strengthening exercises. Responses were dichotomized into "3 or more times per week" and "less than three times per week," as suggested in the Physical Activity Guidelines [28]. Physical activity measures used in COMPASS were found to be both reliable and valid [29].

Dietary behaviours. Five items were used to assess dietary behaviours. (1) Breakfast consumption was assessed by asking students if they eat breakfast daily. Students answering "no" to eating breakfast everyday were considered "low breakfast eaters." (2) Fast food consumption was measured by asking students how many times per week they consumed fast food - those consuming one or more days per week were considered "fast food consumers." (3) Snacking behaviour was assessed by asking students how many times per week they purchased snacks from a vending machine, corner store, snack bar, or canteen off school property – those purchasing snacks off school property one or more times per week were considered "snackers." (4) Sugar-sweetened beverage consumption was assessed by asking students how many days, in a usual school week, they drink sugar-sweetened beverages (soda-pop, Kool-Aid, Gatorade, etc.). Those reporting sugar-sweetened beverage consumption three or more days per week were considered "high pop drinkers." Finally, (5) fruit and vegetable consumption was assessed by asking students to record the number of servings of fruits and vegetables they had eaten the day prior to the survey. Diagrams of Canada's Food Guide serving sizes were included in the Cq for reference [30]. Based on a more conservative estimate of the health benefits of fruit and vegetable consumption, students were dichotomized into those consuming less than five servings and those consuming five or more servings of fruits or vegetables daily [30]. The measure for fruit and vegetable consumption used in COMPASS has been found to be both valid and reliable [31].

Sedentary Behaviours. Three items were used to assess sedentary behaviour. Students were asked to record how much time per day they usually spent (1) "watching/streaming TV shows or movies," (2) "playing video/computer games," and (3) "surfing the internet" These measures were found to be reliable and valid for use in this sample [29]. Each behaviour was dichotomized into categories of "low" (less than two hours) or "high" (two hours or more), based on the Canadian Sedentary Behaviour Guidelines [32],

Substance use behaviours. Three substance use behaviours were included: smoking, marijuana use, and binge drinking. Consistent with previous research, students were classified as (1) smokers if they reported smoking 100 or more cigarettes (in their lifetime), and smoking at least once in the previous 30 days, or reported using another form of combustible tobacco products (e.g., cigars, cigarillos, roll-your-own tobacco, bidis). (2) Current marijuana users were classified as those who had used marijuana at least once in the last month. (3) Current binge drinkers (i.e., consuming 5 or more drinks on one

occasion) were classified as those reporting binge drinking at least once in the last month [19]. Those reporting otherwise were considered non-smokers, non-marijuana users, and non-binge drinkers.

Outcome – overweight/obesity

Students' self-reported height and weight were used to calculate body mass index (BMI). Students were classified as normal weight (in this case, combined underweight and normal weight) (corresponding to <24.9 kg/m^2) or overweight/obese (corresponding to ≥25 kg/m^2) based on the World Health Organization's age- and sex-adjusted BMI cut-points [33], and as used in other studies with the same sample of youth [11]. Height and weight measures were validated in a sample of grade 9 students from Ontario, Canada, and both were found to be both highly reliable and valid [31]. Since this study and COMPASS as a project were not meant to be representative, those students with missing BMI data were dropped from the sample.

Covariates

Students self-reported gender (male, female), grade (9, 10, 11, 12), race (White, Aboriginal [First Nations, Métis, Inuit], other), and weekly spending money ($0, $1-$20, $21-$100, more than $100, "I don't know"). These were considered covariates based on previous research examining youth health behaviours and BMI [12,35].

Statistical Analyses

Frequencies for all modifiable health and risk behaviours, demographic information, and outcome measures were examined across the sample using complete case methods (available cases for behaviours, complete cases for outcome measures).

Latent class analysis (LCA) was used to identify distinct classes, or "clusters" of obesity-related health behaviour patterns based on the combinations of observed behaviours. Indicators chosen for the latent class models included the aforementioned 15 health behaviours previously described. LCA uses observed categorical indicators to examine varying groupings and response patterns, and identifies unobserved classes of respondents [36]. Four model selection criteria were used to identify the appropriate number of classes: Akaike information criterion (AIC) [37], Bayesian information criterion (BIC) [38], Consistent Akaike information criterion (CAIC) [39], and adjusted Bayesian information criterion (a-BIC) [39]. Models with 1-6 classes were examined – those with lower values for the model selection criteria are assessed to have a better overall fit to the data [37]. These model selection criteria, combined with model interpretability and posterior probabilities of belonging to a latent class, were used to place participants into an appropriate latent classes. Missing data on individual health behaviours were handled using the expectation-maximization algorithm, and are considered to be missing at random [37]. Given that LCA is a person-centered approach, used to

uncover homogeneous groups based on the structure of the data rather than preconceived assumptions of health behaviours and how they might co-occur, results can offer important implications for targeting health promotion strategies to those at greatest risk of overweight and obesity [40].

The association between latent class membership and BMI was examined using a logistic regression model that adjusted for covariates. Analyses considered the clustered nature of the data, and included schools as clusters. All analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC).

Results

Study Participants

A total of 30,147 students in grades 9 to 12 were enrolled in the 43 COMPASS secondary schools in year 1 (Y1). Overall, 80.2% (n=24,173) of eligible Y1 students completed the Cq in class time on the day of the scheduled data collection. Non-responses resulted from student absenteeism (19%), parent refusal (0.9%) or student refusal (0.1%). An additional 5,530 students were missing information on student height, weight (5,274), or other covariates of interest (gender, race, grade, or spending money) and were excluded from the analyses. The final complete case sample included 18,587 students. In comparison to the total sample, the final sample for this study included slightly more males (1.1%), fewer students from grade 9 (2.1%), and slightly more students from grades 11 (1.0%) and 12 (1.6%).

Participant Characteristics

Participant characteristics for the 15 health behaviours examined using LCA are summarized for the total sample and by gender in Table 2. Approximately half of the participants were male (51.1%), 73% were White, and over one quarter were overweight or obese (25.6%). Gender differences were observed in all but one health behaviour (time spent watching TV). Overweight/obesity was found more commonly among males (31%) than females (19.3%).

Table 2. Participant characteristics and health behaviours of students participating in Year 1 (2012-13) of the COMPASS Study in Ontario, Canada

	Total % (n=18,587)
Sex (%)	
Male	51.1
Female	48.9
Grade	
9	24.0
10	25.7
11	25.2
12	25.2
Race	

White	73.3
Aboriginal (Off-Reserve)	2.6
Other	24.1
Weekly spending money	
$0	14.7
$1 to $20	30.0
$21 to $100	28.5
More than $100	15.3
I don't know	11.5
Body Mass Index	
Underweight	1.8
Healthy weight	72.6
Overweight	17.7
Obese	7.9
Physical activity	
Physical activity	
< 60 minutes/day	50.5
Missing (#)	352
Strength training	
≥ 3 days per week	40.2
Missing	153
Participates in school intramurals	
No	59.4
Missing (#)	141
Participates in varsity sports	
No	54.3
Missing (#)	136
Dietary behaviours	
Breakfast consumption	
I do not eat breakfast everyday	52.9
Missing	241
Fruit and vegetable consumption	
< 5 servings/day	74.3
Missing	338
Fast food consumption	
≥ 1 time per week	67.5
Missing	443
Snacks purchased off of school property	
≥ 1 time per week	35.2
Missing (#)	508
Sugar sweetened beverage consumption	
≥ 4 days per week	34.8
Missing	482
Sedentary behaviour	
Internet Surfing	
≥ 2 hours/day	48.8
Missing (#)	16
Video Games	
≥ 2 hours/day	29.9
Missing (#)	16

Television	
≥ 2 hours/day	52.7
Missing (#)	16
Other Risky Behaviours	
Current tobacco user	
Yes	13.9
Current binge drinker	
Yes	25.1
Missing	63
Current marijuana user	
Yes	19.4

Model fit and selection

Model fit information for models examining 1–6 latent classes is presented in Table 3. A 4-class model was selected as the best-fitting model as it had lower values for each of the model selection criteria, and a more appropriate interpretation than both its smaller and larger counterparts.

Table 3. Model fit information for the latent class models, 1-6 classes (n=18,587) from Year 1 of the COMPASS Study in Ontario, Canada (2012-13)

Number of classes	AIC	BIC	CAIC	a-BIC
1	39724.56	39842.01	39857.01	39794.34
2	31636.81	31879.55	31910.55	31781.03
3	23881.12	24249.14	24296.14	24099.78
4	**22233.05**	**22526.14**	**22789.35**	**22526.14**
5	20721.96	21340.54	21419.54	21089.49
6	19861.71	20605.61	20700.61	20303.71

AIC Akaike information criterion, BIC Bayesian information criterion, CAIC consistent Akaike information criterion and a-BIC adjusted Bayesian information criterion. The latent class model chosen is bolded.

Class Description

The four classes identified in this study, defined by their clustered health behaviours, were named: *traditional school athletes, inactive screenagers, health conscious,* and *moderately active substance users*. Item response probabilities to the health behaviours across the classes are presented graphically in Figure 6. *Health conscious* youth, appeared to have the overall healthiest item response probability profile across the latent classes. The *inactive screenagers* and *moderately active substance users* had higher item response probabilities for a larger number of obesity-related and substance use behaviours.

The first latent class (*traditional school athletes*) included 24% of the sample, and was represented by the highest proportion of youth reporting 60 minutes of daily physical activity (64%), and of participating in intramural (87%) and varsity sports (99%). Aside from cluster 4, a higher

proportion of participants in this subgroup were binge drinkers (26%) and marijuana users (9.5%). This subgroup was among the highest in sugar-sweetened beverage consumption (46%), as well as snacking (49%) and fast food consumption (81.5%).

The second latent class (*inactive screenagers*) included 43.3% of the sample, and was characterized by a large number of risky health behaviours – the lowest proportion of youth achieving 60 minutes of daily physical activity (37%), engaging in strength training at least 3 times per week (26%), and participating in either intramural (11.2%) or varsity sports (8%). Many of the *inactive screenagers* also spent 2 or more hours watching TV (59%), surfing the internet (58%) and playing video games (35%).

The third latent class (*health conscious*), included 16% of the sample, and was characterized by higher physical activity – strength training (59%), intramurals (62%) and varsity sports (73%), the highest proportion of youth consuming breakfast daily (79.5%), and refraining from fast food (71.6%), other snack (93.6%), and sugar-sweetened beverage consumption (93.7%). This subgroup of youth was also the least sedentary, and only few engaged in binge drinking.

Finally, latent class 4 (*moderately active substance users*) included 16.6% of the sample, and was characterized by the highest proportion of youth engaging in risky behaviours: 70% were tobacco users, 79% binge drinkers, and 83% marijuana users. Youth in this subgroup were also the highest consumers of fast food (85%), sugar-sweetened beverages (47%), and snacks from off-school property (52%). While this group reported being moderately active, they were among the highest consumers of screens, with 57% surfing the internet and watching television for two or more hours per day.
For a more detailed description of the behavioural clusters, see
Table 13 in Appendix E.

Latent Class Relations to BMI

There was a significant relationship between the latent classes and weight status (chi-square = 44.39, $p<0.0001$), with overweight and obesity least represented in the "health conscious" cluster. The highest proportion of overweight/obese youth were in the *moderately active substance users* (28.3%); 26.1% of *inactive screenagers* and 25.6% of *traditional school athletes* were overweight/obese, while only 21.1% of *health conscious* youth were overweight/obese. See Appendix E, Figure 13.

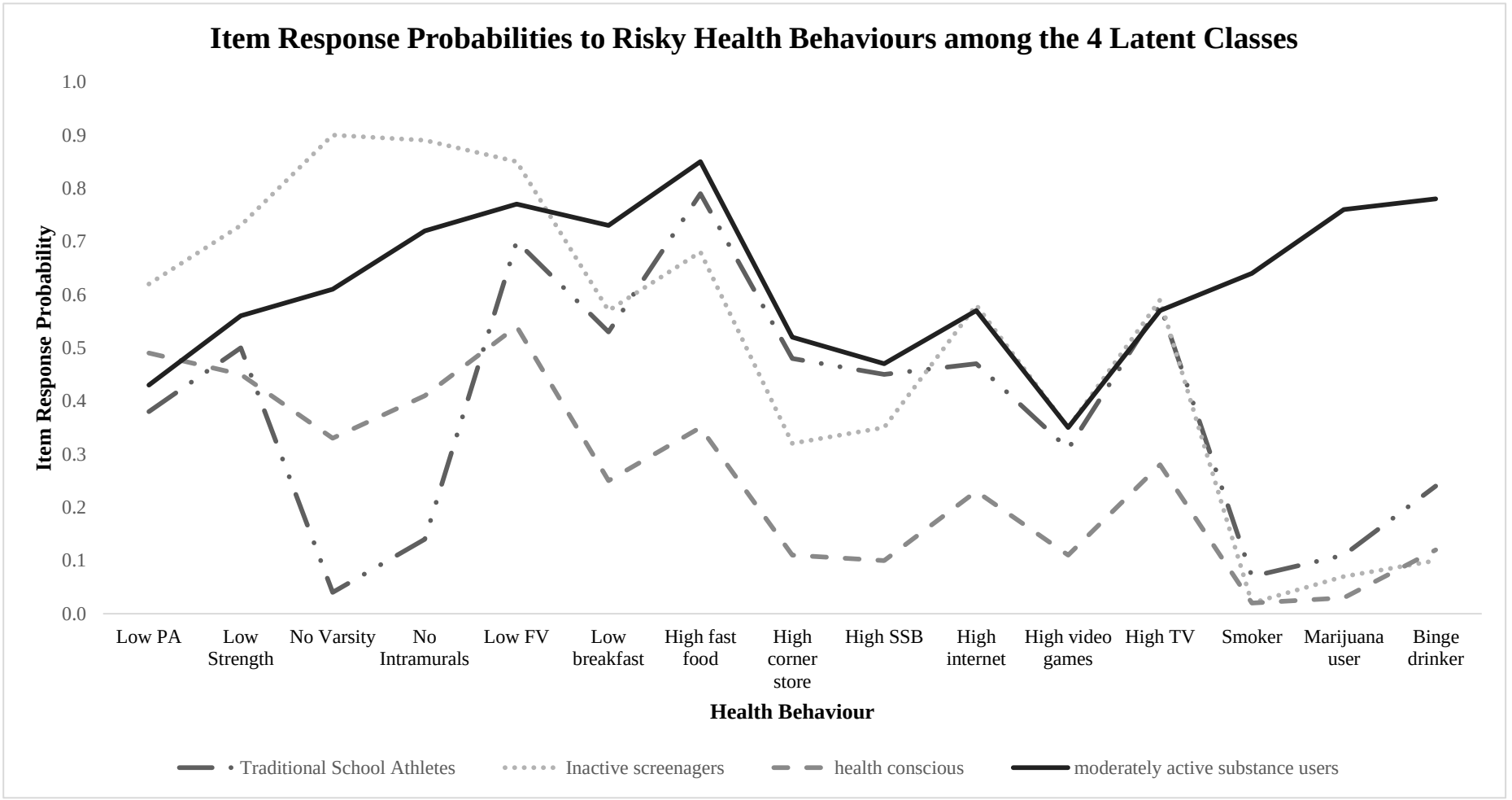

Figure 6. Graphical display of item-response probabilities for health behaviours across the four classes resulting from the LCA in the total sample (n=18,587) from Year 1 (2012-13) of the COMPASS Study in Ontario, Canada.

Regression Analyses

The association between latent class membership and BMI is presented in Table 4. Participants from the *traditional school athletes*, *inactive screenagers*, and the *moderately active substance users* groups had higher odds of being classified as overweight or obese, compared to those belonging to the *health conscious* group. *The traditional school athletes* were 1.15 (95% CI 1.03-1.29) times more likely to be classified as overweight or obese compared to the healthiest subgroup, while *inactive screenagers* and *moderately active substance users* were 1.33 (95% CI 1.19-1.48) and 1.27 (95% CI 1.14-1.43) times more likely, respectively, to be overweight or obese compared to the *health conscious* group.

Table 4. Adjusted odds ratio of being overweight/obese according by latent class for the total sample from Year 1 (2012-13) of the COMPASS Study in Ontario, Canada

Latent classes	**OR (95% CI)**
Health Conscious (Latent class 3)	1.00
Traditional School Athletes (Latent class 1)	1.15 (1.03-1.29)[a]
Inactive Screenagers (Latent class 2)	1.33 (1.19-1.48)[b]
Moderately Active Substance Users (Latent class 4)	1.27 (1.14-1.43)[c]

Models were adjusted for grade, gender, race and total spending money
a: p=0.0099
b: p<.0001
c: p<.0001

Discussion

This study used latent class and regression analyses to examine patterns of modifiable health behaviours and their association with overweight and obesity in a large sample of youth from Ontario, Canada. The health behaviours and proportion of youth that were overweight or obese in the sample were consistent with other Canadian studies [11,18]. Results from this study demonstrated four complex combinations of health behaviours among adolescent subgroups, three of which comprised students exhibiting poorer health behaviours, increasing their risk of being classified as overweight or obese. Identifying and understanding distinct patterns of health behaviours may help researchers better understand etiological factors of overweight or obesity among youth, and might have important implications for health promotion and public health efforts [14].

A number of studies have investigated the co-occurrence of modifiable behaviours in youth [18,41,42], providing insight into the types of behaviours in which youth engage. However these studies have been limited as they did not include the mechanism with which particular subgroups of youth engage in similar behavioural patterns. For example, researchers used confirmatory factor

analysis to identify an underlying factor for the co-occurrence of behaviours, concluding that a "substance use risk factor" and an "unhealthy eating and sedentary factor" explained youths' health behaviours. Based on their findings, it would make sense that these factors could be targeted in health behaviour change interventions [41]. However, this might be misleading since the two factors are likely not mutually exclusive – as seen in the present study, substance use behaviours tended to cluster with obesity-related behaviours. As such, cluster techniques such as LCA can provide better insight about patterns of health behaviours, especially those that may not seem intuitively related. One such explanation might include problem-behaviour theory, which suggests an underlying behavioural syndrome drives youth to adopt multiple problem behaviours, possibly caused by an imbalance of risk factors relative to protective factors across personality and socio-environmental domains [43]. Using LCA or analogous clustering methodologies extends the notion that risky behaviours co-occur, but do so in interesting ways that might warrant specific prevention approaches for different risky behaviours in youth.

The literature on overweight and obesity in youth has largely centered around physical inactivity, sedentary behaviour and poor dietary behaviours. Our findings demonstrate that other risky behaviours, including substance use, tend to cluster with these behaviours, suggesting that obesity prevention efforts must move beyond the focus on just physical activity and healthy eating to include substance use and specific screen-based behaviours [44,45,46]. In one study, adolescents reporting low levels of physical activity also reported high cigarette smoking, low fruit and vegetable consumption, higher TV watching, failure to wear a seatbelt, and a low perception of academic performance. These authors speculated that intervening on one risky health behaviour might have an effect on reducing other negative health behaviours. To promote healthy behaviours among youth at the critical stage of behavioural development [47] and in an effort to reduce overweight/obesity, it is important to understand optimal behavioural patterns and to place emphasis on strategies that target overall behavioural patterns, rather than single behaviours [14,48,], as well as evaluation studies to investigate their effectiveness.

While *traditional school athletes* were more likely to participate in intramural and varsity sports and to accumulate 60 minutes of physical activity daily, expectedly, youth in this group were also more likely to binge drink and to use marijuana – considerably more than the *health conscious* and *inactive screenagers*. This makes sense, given the school athlete, or "jock" archetype has often been associated with heavy drinking behaviours [49,50]. This is similar to previous research by Laska and colleagues, who identified that a "classic" jock subgroup among young adults had the lowest probability of inadequate physical activity, and a higher probability of binge drinking, intoxicated sex, and drunk driving, compared to the other classes [23]. While the *traditional school athletes* were

identified as being at greater risk of overweight and obesity than the *health conscious* students, this might be explained by the greater amount of muscle mass often held by athletes, which contributes to a higher BMI – sometimes identifying healthy athletes as overweight or obese. Laska's research had other similarities, a *health conscious* subgroup, characterized by females with favourable diet and physical activity characteristics; however, these females also had the highest probability of unhealthy weight control behaviours [23]. Similar behaviours were found to cluster among university students [51] and adults [52].

Despite the fact that some behavioural clusters were healthier than others, there was a bleak image of the overall health of students in this sample, with all classes exhibiting at least one risky behaviour. This was consistent with national evidence [9]. Fewer than 1 in 5 students in this study belonged to the *health conscious* cluster and were at a lower risk of overweight and obesity. Despite this, even the *health conscious* subgroup, which seemingly had a more favourable behavioural profile, was comprised of youth not meeting behavioural recommendations and engaging in risky behaviours. This was consistent with another study, in which subjects in all latent classes exhibited at least one risky behaviour [23]. The one risky behaviour found across all four clusters was inadequate fruit and vegetable consumption. This was not surprising; Rossiter and colleagues found that among students in grade 9, only 4% of males and 7% of females were meeting Canada's Food Guide recommendations for 7–8 servings of fruit and vegetables [53]. Knowing this, the current study used a loose interpretation of this Guideline, measuring the proportion of youth consuming a minimum of five servings, as recommended by the CDC [25]. Despite the use of this lower limit, the proportion of youth adhering was still low. This was also not surprising, given that ample research has demonstrated that Canadian adolescents have poor diets [54], including low fruit and vegetable consumption [9], and frequent breakfast skipping and meal consumption away from home [55,56].

To date, obesity prevention initiatives targeting adolescents have had limited success [16]. This might be because they are school- or community-based, and include all students in order to avoid stigmatization, or because the interventions have targeted a limited number of risky behaviours. These approaches target heterogeneous groups of youth, many of which might not benefit from such interventions. Identifying subgroups could allow researchers to better target formative research and design effective interventions, as well as highlight areas for future research and interventions that could target both broad and specific lifestyle factors. Latent class analysis might allow researchers and public health professionals to tailor interventions to specific and appropriate subgroups for more refined and effective interventions [12,57]. This approach can be used to identify the subgroups at greatest risk so that interventions can be more appropriately developed [58]. For example, latent class analysis can provide the evidence required for appropriate audience segmentation for the application of social

marketing principles [57]. Future studies can take these analyses further, and refine groups by gender, race, grade, or other non-modifiable characteristics, which may allow for finer and more tailored interventions.

Strengths of this study include the large sample size, high response rate, and the comprehensiveness of the health behaviours examined. This is the first study in Canada or other countries to examine the clustering of such a large number of behavioural risk factors among youth using latent class analysis, and has included the largest sample size to date in this field. Similar methodologies, such as factor and cluster analyses, generate clusters based on empirical rather than theoretical evidence; by pairing the latent class analysis results with model interpretability, our findings provide more substantial evidence of the complexity of youths' behavioural patterns, thereby better identifying high-risk groups for targeted interventions that use integrated approaches accounting for multiple obesity-related health behaviours.

There are several limitations to this study, most notably the use of cross-sectional data, which prevents causal inferences from being made. While many of the behaviours examined in this study have an intuitive causal relationship with overweight/obesity, there are some cases in which being overweight or obese might increase one's risk of engaging in risky health behaviours. Longitudinal research, which can be facilitated using the COMPASS study, is needed to follow the outcome of behavioural patterns over time. Second, this study relied on self-reported behaviour and outcome measures, which may be subject to social desirability bias [59]. Although objective measures are ideal, they are not possible given the sample size and geographic spread of COMPASS. And while most of the measures used in this study were found to be reliable and valid, it is possible that the effects in this study were underestimated [51]. However, similar measures of youth behaviours have been appropriate for use in previous studies [13]. Third, while there might be other health behaviours found to be associated with BMI in youth, it was not possible to examine all in this study. However, this study included a more comprehensive list of health behaviours than has been used previously. Fourth, although the sedentary behaviour guidelines suggest limiting recreational screen time to a maximum of two hours daily [32], we chose to include each type of screen time individually, dichotomizing each into less than or more than two hours. Had we not, we might have witnessed a ceiling effect, where the majority of the sample was engaging in two or more hours of screen time, thus making it difficult to identify any particular patterns in their health behaviours [18] and underestimating total youth screen time. Fifth, there was some missing information on some of the health behaviours and our latent class analysis assumed these to be missing at random [36], which may have led to a potential misrepresentation of the classes. Less than 2% of students were missing data on any of the behaviours, so this was not likely to be a major problem. Further, COMPASS does not collect data on family-level

or neighbourhood-level socio-demographics. Similar to the multi-dimensional nature of health behaviours and their co-occurrence, socio-demographic factors at both the family and neighbourhood levels have an influence on health behaviours and health outcomes [62] and would be worth exploring and including in future studies. Finally, clusters and data analyses are driven by the data, and therefore not necessarily generalizable beyond this population. However, the behaviours examined in this study and the behavioural responses of students tend to match those from previous research [11,58].

Despite these limitations, the findings from this study have important implications for public health and school-based health promotion initiatives. First, although there was limited variability in BMI across the groups, the healthiest cluster still exhibited some unhealthy behaviours, suggesting that all youth, regardless of their health behaviour cluster, might benefit from some level of intervention. Second, this paper provides further evidence that health behaviours do not occur in isolation, and that a comprehensive approach that considers the clustering of health behaviours is ideal for promoting health behaviours and reducing chronic disease in youth [60]**.** Such an integrated approach, targeting several risky behaviours, along with ensuring supportive environments within which youth can adopt healthy behaviours, can more likely change the trajectory of children's health and health behaviours. This can be done through school programs and resources that integrate different aspects of health and well-being. Tailored approaches are more effective and have greater potential of reaching the appropriate audiences than population-based approaches [61]. For example, targeting an obesity-prevention initiative at *traditional school athletes* might focus on reducing binge drinking and marijuana use, rather than focusing on a message to increase physical activity, since the *traditional school athletes* are sufficiently active. This might be achieved through a substance-use policy in schools for athletes, whereby athletes joining sports teams sign a contract and commit their abstinence to substance use and a guarantee to maintain healthy nutrition and reduce their screen time. *Moderately active substance users* were those who used several substances and who engaged in other risky behaviours that typically co-occur with substance use. These youth might be best reached by harm reduction and education on substance abuse and poor nutrition, and by reducing the amount of time spent watching TV and surfing the internet This group might also be reached by promoting intramurals, which might replace some screen time and reduce their risk of engaging in other risky behaviours. Finally, the *inactive screenagers*, demonstrating the lowest physical activity and highest screen time, might be targeted by promoting fun and engaging physical activity opportunities to replace time spent on screens. Increasing access to affordable fruits and vegetables, or creating urban gardens in schools and communities, might increase fruit and vegetable consumption among all youth, a risk behaviour common to all four health behaviour clusters [63].

Conclusions

Examining the patterns of obesity-related and other risky health behaviours, four subgroups of participants were identified in a large sample of youth from Ontario, Canada. Results reaffirm that not only do health behaviours co-occur, but they often do so in varying patterns, which can create challenges when designing public health interventions and population health prevention strategies. In this study, youth that belonged to all three of the clusters considered less healthy were at greater risk of being overweight/obese compared to youth with the healthiest behaviour patterns. To optimize limited prevention resources, it might be beneficial for public health interventions to target multiple modifiable risk factors that tend to cluster, tailored to particular subgroups of youth.

Chapter 5
Manuscript 2: Behavioural patterns only predict concurrent BMI status and not BMI trajectories in a sample of youth in Ontario, Canada

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Brief Overview and Purpose

This chapter is a copy of the manuscript that was submitted to PLOS ONE. All supplementary material and additional information can be found in Appendix F.

In the first manuscript, I identified that there were four distinct patterns of behaviour that emerged from the data: *Traditional School Athlete, Inactive Screenagers, Health Conscious,* and *Moderately Active Substance Users*. The *Traditional School Athletes, Inactive Screenagers,* and *Moderately Active Substance Users* were all at greater risk of overweight and obesity compared to the *Health Conscious* cluster. I used a linked-longitudinal sample to examine the effect of engaging in these patterns of risky behaviours on youths' BMI trajectories, following students for three years, and to identify if engaging in particular patterns of risky behaviours at baseline could predict BMI trajectories. Public health interventions targeting youth subgroups at greatest risk of overweight or obesity through integrated approaches accounting for the multiple risk behaviours should be considered, especially for the subgroups found to be most significantly associated with steeper BMI trajectories and to have greater risk of developing overweight or obesity.

Outline

Background: Youth are engaging in multiple risky behaviours, increasing their risk of overweight, obesity, and related chronic diseases. The objective of this study was to examine the effect of engaging in unique clusters of unhealthy behaviours on youths' body mass index (BMI) trajectories.

Methods: This study used a linked-longitudinal sample of Grades 9 and 10 students participating in the COMPASS host study. Students reported obesity-related and other risky behaviours at baseline and height and weight (to derive BMI) at baseline and annually for 2 years post-baseline. Students were grouped into behavioural clusters based on response probabilities from a previous latent class analysis investigation. Linear mixed effects models, using BMI as a continuous outcome measure, were used to examine the effect of engaging in clusters of risky behaviours at baseline on BMI trajectories.

Results: There were significant differences in BMI for the four behavioural clusters at baseline that remained consistent over time. Higher BMI values were found among youth classified at baseline to be *Traditional School Athletes* (β = 0.232 kg/m^2, [confidence interval (CI): 0.03-0.50]), *Inactive Screenagers* (β = 0.348 kg/m^2, CI: 0.11-0.59) and *Moderately Active Substance Users* (β = 0.759 kg/m^2, CI: 0.36-1.15) compared to students classified as *Health Conscious*. Despite these baseline differences, BMI appeared to increase across all behavioural clusters annually by the same amount (β = 0.6097 kg/m^2, CI: 0.57-0.64).

Conclusions: Although annual increases in BMI did not differ by behavioural clusters, membership in a particular behavioural cluster was associated with baseline BMI, and these differences remained consistent over time. Results indicate that intervening and modifying unhealthy behaviours earlier might have a greater impact than during adolescence. Health promotion strategies targeting the highest risk youth as they enter secondary school might be promising means to prevent or delay the onset of obesity.

Introduction

There has been a notable increase in the prevalence of both measured and self-reported overweight and obesity over the last 30 years, with obesity rates tripling from 3% to over 9% among Canadian youth aged 12-17 years [1]. Obesity in adolescence is associated with an increased risk of adult obesity and other chronic diseases, including cardiovascular disease, diabetes, and hypertension [2]. Overweight youth also tend to be at risk for psychosocial problems, to complete fewer years of higher education, and subsequently to live in households with lower average incomes [2, 3]. There is a need to better understand the causes and correlates of overweight and obesity in adolescence.

The positive energy balance contributing to overweight and obesity through low levels of physical activity and poor dietary behaviours is often the focus in obesity research [4]. However, total fat and energy intake have remained relatively constant, suggesting that other behaviours might be more influential of adolescent weight status. For example, advances in technlogy have led to a marked increase in screen time and sedentary behaviour among adolescents, which is often coupled with lower energy expenditure. Other risk behaviours that tend to emerge in adolescence, such as alcohol consumption [5] and cigarette smoking have also been linked to an increase in percent body fat, overweight, and obesity [6]. However, the mechanism by which these behaviours contribute to overweight or obesity is not well understood. And while individually linked to an increased risk of overweight and obesity in youth [7, 8], these behaviours do not occur in isolation, but rather cluster in unique ways [9, 10, 11]. Since most youth are not engaging in optimal behavioural patterns [9, 10, 12] and report engaging in at least one modifiable risk behaviour [12], there is a reinforced need for prevention programming targeting youth.

Evidence from cross-sectional studies has demonstrated an association between risky behavioural clusters and obesity among children and youth [10, 11]. While useful for surveillance of youth risk behaviours, cross-sectional studies do not provide the necessary data to quantify trajectories at the individual level [13], nor to examine a temporal relationship between risky behavioural patterns and body mass index (BMI). The existing longitudinal research focused on single behaviours, and suggests that among children, behaviours protective of healthy body weights include physical activity [14, 15, 16], sports participation [17], low sedentary behaviours [14, 15, 18, 19], and a healthier diet [20]. However, little is known about other risky behaviours (smoking, marijuana use, binge drinking), or the combined effect of these behaviours on BMI trajectories.

Prevention and intervention programs, frequently developed to target specific behaviours, might be more effective if comprehensive since behaviours rarely occur in isolation [21]. To best target such prevention programming, it is important to understand optimal behaviour patterns and to place emphasis on the strategies that target more complex behavioural patterns rather than single behaviours.

Our objectives were to: (1) examine variation in BMI across distinct combinations of risky behaviours in youth that clustered based on clustering methodology and (2) identify if behavioural cluster membership predicted BMI trajectories in youth. Identifying the behavioural clusters associated with an accelerated BMI trajectory might help researchers better allocate resources and direct efforts to target appropriate modifiable behaviours. Steeper BMI trajectories towards overweight and obesity might suggest the importance of earlier interventions to improve the trajectory of BMI in youth.

Methods

Design

The COMPASS Study (COMPASS) is a prospective cohort study designed to collect hierarchical and longitudinal data from a sample of secondary school students and the schools that they attend in Ontario and Alberta, Canada. This manuscript used data collected from the cohort of 5,085 students in 41 Ontario schools that participated in the first three years: years 1 (Y_1: 2012-2013), 2 (Y_2: 2013-2014), and 3 (Y_3: 2014-2015) of the COMPASS Host Study. Data were obtained from 41 purposefully sampled Ontario schools that agreed to use active-information, passive-consent parental permission protocols. Student-level data were collected annually using the COMPASS questionnaire. A full description of the COMPASS study and its methods is available online (www.compass.uwaterloo.ca) and in print [22]. The COMPASS study received ethics approval from the University of Waterloo Human Research Ethics Committee, as well as from review panels of all participating school boards.

Sample and population

In Y_1, a total of 30,147 students in grades 9 to 12 were enrolled in 43 COMPASS secondary schools. Overall, 80.2% (n=24,173) of eligible Y_1 students completed the questionnaire during class time on the day of the scheduled data collection. Non-responses resulted from student absenteeism (19%), parent refusal (0.9%) or student refusal (0.1%). Records missing information on height, weight, or other covariates of targeted interest (gender, race, grade, or spending money) were excluded from the analysis sample. While additional schools were recruited in Y_2 and Y_3, only the students that participated in Y_1 of COMPASS were included in this manuscript. As described elsewhere [23], self-generated identification codes were used to link data sets for the three years and to create the longitudinal data set for analyses. To ensure a sufficient sample size, this study used available-case analysis [24], including participants that provided behavioural data at Y_1, and BMI data at Y_1 and two years of follow-up (Y_2 and Y_3). Between Y_1 and Y_3, two schools withdrew from COMPASS, and

10,978 graduated from grade 12 (5,699 in Y_1 and 5,279 in Y_2). The final linked longitudinal sample used for this study included 5,084 students from 41 schools in Ontario.

Measures

Outcome variable – BMI

Students' self-reported height (in meters) and weight (in kilograms) were used to calculate BMI (in kg/m^2). The COMPASS BMI measure was validated in a sample of grade 9 students from Ontario, Canada, and demonstrated substantial 1-week test-retest reliability (Intraclass correlation [ICC] = 0.95) and concurrent validity with measured height and weight (ICC = 0.84) [25]. BMI was classified as a continuous outcome measure, as a continuous BMI measure can provide more nuanced information than BMI categories when examining changes to BMI over short time periods [26].

Predictor variables – risk behaviour clusters

The risk behaviour clusters used for this study are those identified in previous research using Y_1 COMPASS data [10]. A latent class analysis (LCA) to identify patterns of 15 behavioural indicators associated with overweight and obesity [physical activity (time spent in hard and moderate physical activity, days engaging in strength training, physical activities organized by the school, and participation on a competitive school sports teams), dietary behaviours (breakfast consumption, fast food consumption, snacking behaviour, sugar-sweetened beverage consumption, and fruit and vegetable consumption), sedentary behaviour (time spent watching television, playing video/computer games, and surfing the internet), and substance use behaviours (smoking, marijuana use, and binge drinking)] was conducted on a subsample of youth (n=18,587) participating in Y_1 of COMPASS [10]. Results from the LCA identified four unique behavioural clusters: 1) *Traditional School Athletes*; 2) *Inactive Screenagers*; 3) *Health Conscious*; and, 4) *Moderately Active Substance Users* to which youth were assigned based on highest probability of group membership [10, 27]. Behaviour cluster membership at baseline was used to predict youths' BMI trajectories.

Covariates

Sociodemographic characteristics were measured at Y_1. Covariates considered in the analyses were found previously to be associated with BMI and health behaviours in youth, and included students' self-reported gender (male, female), grade (9, 10, 11, 12), race (White, Aboriginal [First Nations, Métis, Inuit], other), and self-reported average weekly spending money ($0, $1-$20, $21-$100, more than $100, "I don't know") [28].

Statistical analysis

All analyses were performed using the statistical package SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Descriptive statistics were calculated for the total sample.

We used PROC MIXED to fit 3-level linear mixed effects models (level 1 – school; level 2 – students within schools; and 3 – repeated BMI measures over time within students) [29]. Using three years of data, the models tested the effects of engaging in risky behaviours at baseline or of belonging to a particular behaviour cluster on youths' BMI trajectories. An initial null model was executed to examine variability in BMI that can be attributed to the clustered nature of the data and to identify if school (as a cluster variable) was necessary to include in the models. Although small, variability across the schools was significant, and school as a cluster variable was therefore considered in all subsequent models. We considered three models of behavioural cluster membership on BMI trajectories, considering BMI as a continuous outcome measure: controlling for year (Model 1), controlling for year, gender, grade, race, and weekly spending money (Model 2), and lastly, Model 2 control variables with test for interaction between time and behavioural cluster. All models controlled for year in the analyses.

Results

At Y_1, 17.7% of youth were overweight and 7.9% were obese. As identified in a previous paper (14), youth that belonged to less healthy behavioural clusters compared to the *Health Conscious* cluster were considered to be at an increased risk of overweight and obesity. Details on the identification of the four behavioural clusters are described elsewhere [10] (in Chapter 4: Manuscript 1).

Description of the study sample

Participant characteristics for the total linked sample (n=5,084) and by behavioural cluster can be found in Table 5. Approximately half of the students were female (52.1%), a large majority were White (75.8%), and most were in Grades 9 (46.5%) or 10 (50.9%). The behavioural cluster most strongly represented in this sample was the *Inactive Screenagers* (44.9%), while the *Moderately Active Substance Users* was the least represented (7.8%). The mean BMI of the total sample at baseline was 21.3 kg/m^2, with the lowest BMI found among the *Health Conscious* youth (20.9 kg/m^2) and the highest among the *Moderately Active Substance Users* (22.1 kg/m^2).

Table 5. Baseline characteristics of the linked-longitudinal sample of youth participating in Y_1 to Y_3 of the COMPASS Study in Ontario, Canada (2012-2015)

Variable	Total (n= 5084)	Traditional School Athlete (n=1419, 27.9%)	Inactive Screenagers (n=2285, 44.9%)	Health Conscious (n=1008, 19.8%)	Moderately Active Substance Users (n=372, 7.3%)
Gender					
Males	2438 (48.0)	22.0	50.7	21.5	5.8
Females	2646 (52.1)	34.3	38.7	18.0	9.0
Race					
White	3854 (75.8)	28.4	43.5	20.9	7.1
Aboriginal	170 (3.3)	22.1	41.4	15.3	21.2
Other	1060 (20.9)	26.7	50.1	16.4	6.8
Grade					
9	2363 (46.5)	27.6	45.9	21.8	4.7
10	2588 (50.9)	28.2	44.0	18.4	9.4
11	133 (2.6)	27.3	46.1	14.1	12.5
Spending money					
None	939 (18.5)	21.6	50.3	24.7	3.4
$1 to $20	1917 (37.7)	27.4	48.8	17.9	5.8
$21 to $100	1246 (24.5)	31.2	41.0	17.7	10.1
More than $100	326 (6.4)	30.4	30.7	18.7	20.3
I do not know	656 (12.9)	30.8	40.7	23.0	5.5
BMI (mean, st dev)	21.3 (3.36)	21.3 (3.18)	21.3 (3.54)	20.9 (3.07)	22.1 (3.46)

Mean BMI increased from 21.3 kg/m^2 in Y_1 to 22.3 kg/m^2 in Y_3. Males' self-reported BMIs (21.7–23.0 kg/m^2) were consistently higher than females' (20.9–21.7 kg/m^2). Figure 7 shows that there was an annual increase in average BMI (0.4 to 1.2 kg/m^2) from Y_1 to Y_3 across all behavioural clusters, with an apparent plateau of BMI among the *Moderately Active Substance Users* from Y_2 to Y_3.

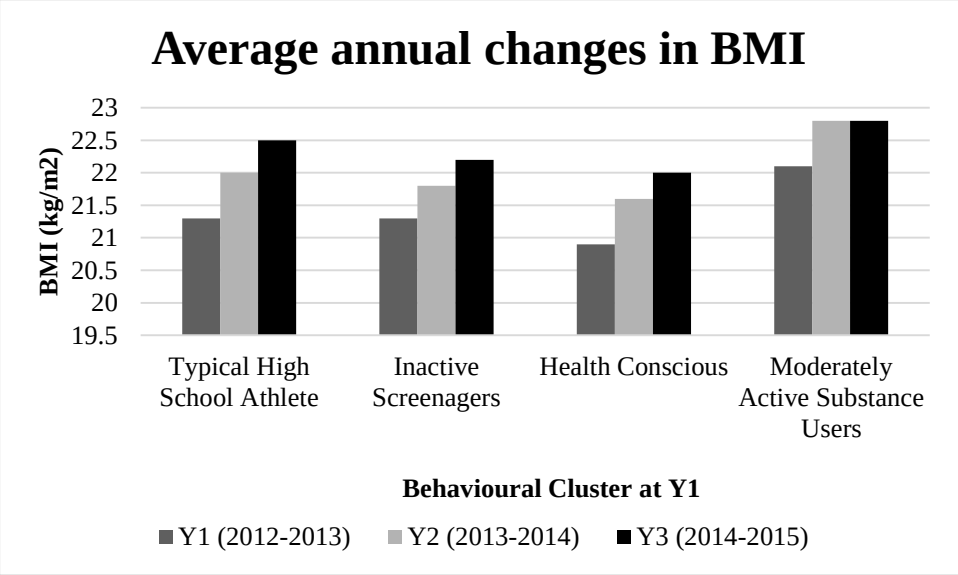

Figure 7. Average annual changes in BMI from the linked longitudinal sample participating in Y_1 to Y_3 of the COMPASS Study in Ontario, Canada (2012–2015)

Mixed effects regression model results

Regression coefficients for all models are found in Table 6. The empty model used to determine the intraclass correlation identified that there was a cluster effect at the school-level that needed to be considered in all subsequent models (ICC = 2%). Results from Model 1, which only controlled for time and school, suggested that all three behavioural clusters were significantly different from the *Health Conscious* cluster, with differences ranging from 0.344 kg/m^2 (*Inactive Screenagers*) to 1.041 kg/m^2 (*Moderately Active Substance Users)*. In model 2, controlling for sociodemographic factors, BMI at baseline for youth belonging to the *Traditional School Athletes* cluster (20.63 kg/m^2, confidence interval (CI) 0.03–0.50) was higher than youth in the *Health Conscious* cluster (β=+0.232 kg/m^2). Similarly, at baseline, BMIs of youth classified as *Inactive Screenagers* (20.57 kg/m^2, 0.11–0.59) and *Moderately Active Substance Users* (22.16 kg/m^2, 0.36–1.15) were higher compared to youth classified as *Health Conscious* (β=+0.348; β=+0.759 kg/m^2, respectively). Model 3 results, which incorporated a time*cluster interaction, were not significant, suggesting that the BMI trajectories of youth belonging to different behavioural clusters were not significantly different. Accordingly, results indicate that if all

youth continue to engage in the same patterns of health and risk behaviours behaviours as identified at baseline, we would predict an increase in BMI of 0.61 kg/m^2 annually (β=0.610 kg/m^2, CI: 0.57–0.64). These projected BMI increases for each cluster are depicted in Figure 8.

Table 6. Regression coefficients for the relationship between risky behavioural clusters at baseline and BMI over time among youth participating in Y_1 to Y_3 of the COMPASS Study in Ontario, Canada (2012-2015)

	Model 1			**Model 2**		
	β	**SE**	**CI**	**B**	**SE**	**CI**
Intercept	21.053	0.1271	20.8-21.3**	20.401	0.1679	20.1–20.7
Time	0.6090	0.0170	0.58-0.64**	0.6097	0.0170	0.57–0.64**
Cluster group						
Traditional school athletes	0.4104	0.1358	0.12-0.68*	0.2317	0.1353	-0.03–0.50
Inactive screenagers	0.3438	0.1250	0.10-0.59*	0.3481	0.1237	0.11–0.59*
Health conscious (ref)	--	--	--	--	--	--
Moderately Active substance users	1.0414	0.2011	0.65-1.44**	0.7592	0.2019	0.36–1.15*
Gender						
Male	--	--	--	1.0117	0.0927	0.83–1.19**
Female (ref)	--	--	--	--	--	--
Grade						
9 (ref)	--	--	--	--	--	--
10	--	--	--	0.4006	0.0940	0.22–0.58**
11	--	--	--	0.8150	0.2977	0.23–1.40
Race						
White (ref)	--	--	--	--	--	--
Aboriginal	--	--	--	0.5584	0.3355	-0.10–1.22
Other	--	--	--	-0.023	0.1158	-0.25–0.20
Weekly Spending money						
$0 (ref)	--	--	--	--	--	--
$1 to $20	--	--	--	0.0122	0.1304	-0.24–0.27
$21 to $100	--	--	--	0.0138	0.1433	-0.27–0.29
More than $100	--	--	--	0.1159	0.2142	-0.46–0.19
I do not know				-0.134	0.1661	-0.30–0.54

CI: Confidence intervals; "ref"= referent category for analyses
** p<.0001
* p<.05

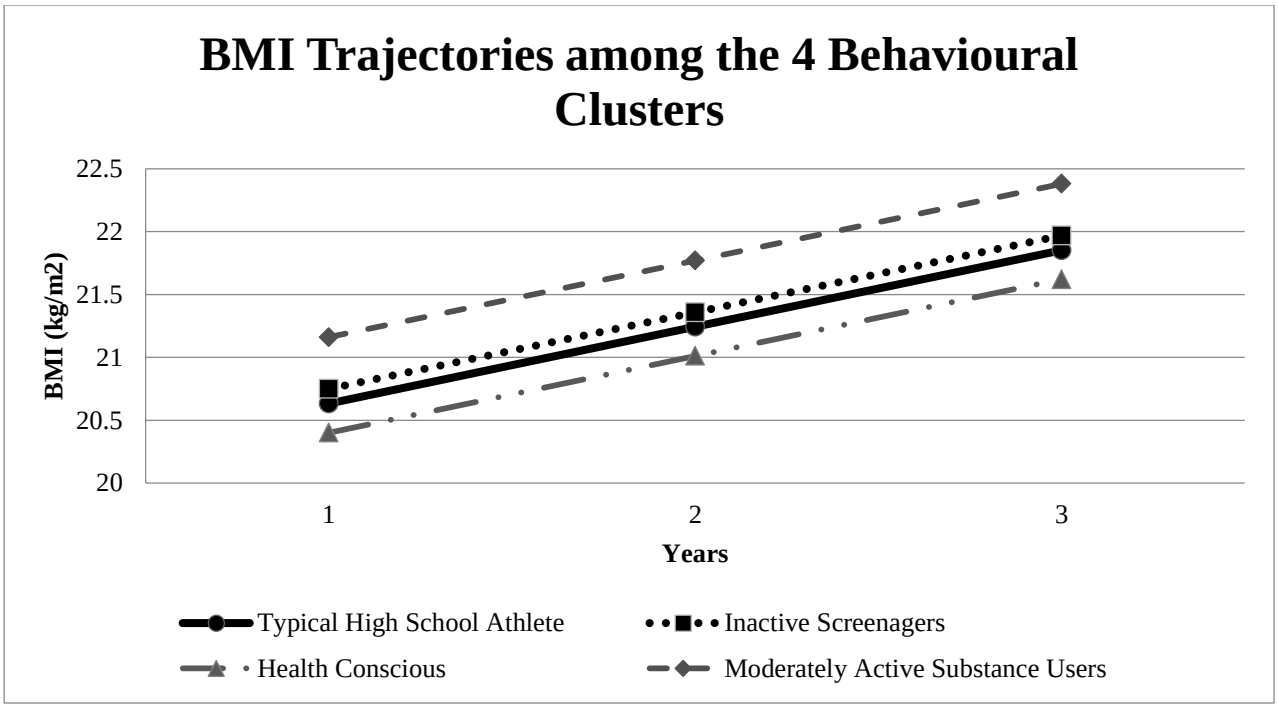

Figure 8. Model-based predicted BMI trajectories of the 4 behavioural clusters from the linked longitudinal sample of youth participating in Y_1 to Y_3 of the COMPASS Study in Ontario, Canada (2012–2015).

Results from the fourth model, that included the interaction term of cluster*time, can be found in Figure 16 in Appendix F.

Discussion

This study investigated the impact of engaging in four distinct clusters of behaviours (*Traditional School Athlete, Inactive Screenagers, Health Conscious, and Moderately Active Substance Users*) on the BMI and BMI trajectories of a large sample of youth from Ontario, Canada. Consistent with previous research [30], there were significant differences in the average BMI at baseline across the four behavioural clusters, suggesting that BMI was associated with concurrent weight status. Despite baseline differences, the BMI trajectory was 0.610 kg/m^2 annually for all youth, irrespective of their behavioural cluster, thus suggesting that engaging in risky behaviours might only predict BMI at baseline and not differences in trajectories. Results did not extend previous research on the correlates contributing to accelerated BMI trajectories, but did confirm that males and older youth have higher BMI trajectories than their counterparts. Efforts are required to improve health behaviours to slow BMI trajectories in all youth belonging to all clusters, considering the heterogeneity of BMI at baseline and noting that some subpopulations might develop overweight or obesity earlier than others based on their baseline BMI [13].

The limited longitudinal research on health behaviours and BMI trajectories to date has been mixed. Some have found that unhealthy weight-related behaviours, including higher caloric consumption, lower physical activity, and higher screen time, are associated with larger increases in BMI over time [15, 31, 32], and that modifying these risk behaviours can improve BMI [16, 32]. Others found that physical activity in adolescence did not predict obesity five years later, but that decreases in screen time during adolescence were associated with lower rates of obesity [34]. This was opposite to the findings of Chinapaw and colleagues, which were that sedentary time in youth was not related to BMI [35]. However, they only focused on television viewing behaviours, which may have underestimated the actual time that youth spend on screen-based behaviours (i.e., video games, cell phone use, internet surfing) [36]. In terms of dietary behaviours, some have identified that energy intake was inversely related to fat mass, opposite to what would be expected based on the theory of energy balance [37, 38]. Overall, however, the general consensus from this research is a need to investigate a combined effect of engaging in multiple behaviours on BMI, rather than focusing on individual behaviours.

The results of this present study suggest that all risk behaviour clusters require attention. The projected BMI trajectories depicted in Appendix F: Figure 16, starting with baseline BMI for all behavioural clusters demonstrates the increase in BMI that each cluster would experience over time, with no behavioural interventions. These estimates might be conservative, as we did not consider the likely increasing prevalence of engaging in risky behaviours and the likelihood of adopting of other risky behaviours as youth leave high school and transition to college, university, or the workforce [39]. Interestingly, the *Moderately Active Substance Users'* BMIs, as seen in Figure 8, appeared to plateau after Y_2. This study used an available case analysis, including students with at least 2 years of BMI data. Many of the missing students in Y_3 belonged to the *Moderately Active Substance Users* cluster. Such characteristics (smoking, marijuana use, binge drinking) are typical among students that tend to skip school and it is possible that they were not present on the day of the survey [40]. As such, the leveling off of BMI in this cluster group may be explained by the missing data.

This study focused on the effect of baseline behavioural cluster membership on BMI trajectories. The use of behaviours at baseline as our predictor variables assumed that behaviours either remain consistent over time, or that the effects of behaviours on BMI might be lagged. Using latent transition models, researchers demonstrated that health behaviours and the ways in which behaviours cluster tend to remain consistent over time in youth [41], and that BMI trajectories established during early-adolescence (aged 8-14 years) remain stable over time among children who are heavier. With the sample in this study, measuring health behaviour clusters as time-variant between baseline and follow-up might better predict BMI trajectories [42]. Considering other factors as potential moderators, such as

body image concerns, weight stigma, or baseline weight status [43, 44], might also help to explain the effects of self-reported behaviours on BMI trajectories.

Since there are few known treatments for reducing or maintaining BMI, a better understanding of the behavioural clusters that most strongly predict BMI at baseline or BMI trajectories might help steer future prevention strategies. This study did not provide the necessary evidence to suggest which behavioural clusters are associated with an accelerated BMI trajectory, since time was the only significant predictor of BMI trajectories among all behavioural clusters. Thus, interventions may be warranted for all groups, targeting the risky behaviours that might be present in all clusters, or the behavioural clusters most strongly associated with concurrent/baseline weight status. Given limited resources, public health practitioners and researchers should still be purposeful in their prevention planning, by targeting obesity through a comprehensive and multi-sectoral response, one that is capable of targeting co-occurring risky behaviours. These are especially important behaviours to target in childhood or adolescence, because once behavioural patterns are established, they are difficult to modify [45].

Most youth in Canada are not meeting guidelines for healthy diets and healthy physical activity [46], and a large proportion are engaging in other risky behaviours, including marijuana use, smoking, and binge drinking [12]. All youth in this study would require attention, but each cluster would benefit from a different type of intervention. Targeting the *Moderately Active Substance Users* is a novel approach; while substance use is generally not a focus of obesity prevention, it does tend to co-occur with other risky behaviours, and there is rarely focus on substance use for obesity prevention. In fact, those that binge drink consume an excess of calories [5], supporting the idea that alcohol may be partially responsible for driving the increase in BMI [5, 47]. The excess calories may be acquired through the alcohol itself, or through consumption of unhealthy foods, which often occurs with binge drinking [47]. Knowing this, researchers might steer away from only focusing on physical activity and dietary behaviour interventions, and instead look towards reducing substance use as a potentially effective and novel approach to addressing youth obesity [48]. The notion that targeting efforts towards substance users might be more effective at preventing or reducing obesity is relevant and timely, given the potentially easy access that youth have to substances – Canada is in the process of legalizing marijuana and Ontario recently began selling beer in grocery stores [49]. Such a targeted approach would require evaluation through ongoing data collection and evaluation systems, such as COMPASS, to evaluate if such policies and natural experiments have unintended consequences on the BMI trajectories of youth.

Although the magnitude of the estimated effects might appear small, they resemble those of earlier longitudinal studies [15, 16], and might lead to substantial increases in BMI and fat mass if

sustained over time. Results emphasize the need to promote healthy behaviours among youth starting at a younger age, while behaviours are beginning to develop and are likely to sustain. One behaviour to target might be fruit and vegetable consumption, which was inadequate across all four behaviour clusters. This is consistent with other research that identified an inverse relationship between BMI and breakfast consumption [16, 20]. However, the results of this study must be interpreted with caution, since the mean BMI was similar across all four groups, suggesting they may not be sufficiently different to draw true comparisons.

Strengths and Limitations

This study has several strengths. Its main strength is its longitudinal design, which could have supported the causality assumption that risky obesity-related health behaviours are associated with BMI trajectories in a large sample of adolescents. Second, this study utilized all available cases instead of only complete cases [24], thus providing a less biased estimate of the effect sizes. The two measures might be equally biased if the missing data were unrelated to the questions of interest, which can never be guaranteed in research on BMI [25]. Another strength of this study was the use of BMI as a continuous measure, thus avoiding potential misclassification of weight status (i.e., normal weight, overweight, obese) that may occur if there was systematic bias in the self-reported height and weight. Further, BMI as a continuous measure is more meaningful in longitudinal research [18], as it considers the entire range of adiposity [15], and can provide a clearer indication of change [18] since it avoids cut-points that are used to define overweight and obesity. Finally, the analytical approach used for this study accounted for the correlation between repeated measurements on the same subjects [50], examined individual and area-level variables in one model to account for clustering of observations, and examined variation between individuals and groups simultaneously [50].

Some limitations must be considered in light of the study's strengths. First, all data in COMPASS are self-reported, which might be subject to social desirability or recall biases. Subjects were assured anonymity when completing the survey, and the majority of measures were found to have acceptable reliability and validity. This is most noteworthy for our outcome measure of BMI, which although crude, demonstrated strong reliability and validity, and is the most feasible method for use in large cohort studies of youth. And since the purpose of this study was to identify how BMI changes over time, it is expected that youth will misreport consistently over time [25]. However, the misreporting is most often an overestimation of height and an underestimation of weight, leading to a "flat slope syndrome," which would underestimate the proportion of youth on a trajectory toward overweight or obesity [25, 51]. Second, the health behaviour clusters were identified in a previous study based on the behavioural response patterns of students in COMPASS Y_1 using latent class

analysis. And since behavioural clusters identified using latent class analysis are determined based on one's highest probability of cluster membership, it is possible that there was overlap and students were assigned to the wrong category. Similarly, the use of the latent classes from a previous study assumed that behaviours remained static and that youth did not transition in or out of other behavioural clusters. Although found to be consistent with previous research, future analyses might consider using a latent trajectory analysis to examine the behavioural clusters over time, concurrently with changes to BMI (Koning, Hoekstra, de Jong, Visscher, Seidell, & Renders, 2016). Third, although BMI was the most feasible outcome measure for this study, it may not have been the most practical. As such, interpreting the BMI of the different behavioural clusters must be done with caution; youth belonging to the *Inactive Screenager* cluster are more likely to have a higher fat mass, while the *Traditional School Athletes* are more likely to have a higher muscle mass, and both possibly have the same BMI [52]. Thus, reducing BMI in the two groups would have different consequences – among the *Inactive Screenagers*, it would mean a reduction in fat mass, while in the *Traditional School Athletes*, it would suggest a reduction in muscle mass, a counterproductive message when the intention is to promote healthy behaviours (i.e., physical activity).

Conclusions and implications

Having insight into how health behaviours cluster together in unique ways to influence BMI or change BMI trajectories might assist in the development of more targeted interventions, especially since the health behaviours comprising the behavioural clusters are modifiable and can be the subject of health promotion programs. However, since behavioural cluster membership was not associated with BMI trajectories, the message to send to program planners is not clear. BMI values across the four clusters differed significantly at baseline, and based on model results, were predicted to remain different over time. Researchers should consider addressing these modifiable behaviours at an earlier age, before they begin to emerge and cluster together. Modifying behaviours once they are established is difficult; therefore, establishing healthier lifestyle behaviours and behavioural patterns earlier in life should be an important public health priority.

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Chapter 6
Manuscript 3: Non-comprehensive and intermittent obesity-related school programming and policies may not work: evidence from the COMPASS study

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Brief Overview and Purpose

The following chapter includes the copy of the manuscript submitted to the Journal of School Health. Supplementary material for this manuscript can be found in Appendix G.

The previous two chapters examined the more proximal factors that might be associated with overweight, obesity, and BMI trajectories. This next chapter moves beyond the individual behavioural factors to examine another level of the socio-ecological model. This manuscript answers the research question: do changes to school-level obesity-related prevention programs and policies between years 1 and 2 of COMPASS have an influence on BMI trajectories in youth, when controlling for the behavioural clusters identified in research question 1? In order to support the development of evidence-based policies promoting broader implementation of successful programs, we need to establish the effectiveness of school programs in the appropriate context. Intensive and multi-faceted school policies and programs have been found to be effective in preventing overweight among some students in elementary schools. Broader implementation of and investment in such programs is justified in that they have a high potential to reduce childhood obesity. Using complex statistical analyses and a linked longitudinal sample of over 4,000 students from Ontario, Canada, we investigated the impact of modifying obesity-related policies and programs on youths' body mass index (BMI) trajectories. This study utilized a quasi-experimental multiple-control research design to explore the relationship between school policy/program changes and BMI trajectories. The methodology was designed so we could detect changes in BMI at the school-level after students were exposed to new programs or policies related to physical activity or healthy eating. BMI pre-"intervention" was measured in the first year of the COMPASS study, with follow-up observations for two subsequent years.

Outline

Background: The school environment has the potential to influence student body mass index (BMI) through policies, programs, and practices. The objective of this study was to examine the effect of modifying obesity-related school policies, programs, and practices on youths' BMI trajectories.

Methods: Obesity-related school policies and programs in the domains of physical activity and healthy eating were collected from 41 schools across Ontario at baseline (2012-2013) and year 2 (2013-2014) of the COMPASS Study, and modifications to the school environment were extracted. Self-reported height and weight were collected from the 4,951 Grades 9 and 10 students who attended those 41 schools for three years. Linear mixed effects regression models examined the effect of modifications to obesity-related school policies, programs, and practices on youths' BMI trajectories.

Results: At baseline, the majority of COMPASS schools offered students opportunities to be physically active and to eat healthily. Between Y_1 and Y_2, 26 of the 41 schools implemented distinct new obesity-related programs or practices in the domains of either physical activity or healthy eating. Only five of the interventions were associated with BMI trajectories of students attending those schools compared to students attending a pooled sample of control schools, predicting a higher BMI trajectory.

Conclusions: The results of this study suggest that isolated programs and policies may not improve youths' BMI trajectories. Further research is required to test the implementation of policies and programs that follow a comprehensive school health approach, targeting BMI and the behaviours associated with an increase in BMI.

Introduction

Excessive weight gain and changes to body mass index (BMI) among youth over time is becoming a larger focus of public health research. Presently, youth in Canada are three times more likely to be overweight than they were 30 years ago, with 31% of boys and 26% of girls classified as overweight (Roberts, Shields, de Groh, Aziz, & Gilberta, 2012). Given the numerous health risks associated with overweight and obesity in youth, and the tracking of overweight and obesity into adulthood (Reilly & Kelly, 2011), it is imperative that efforts and resources are directed at the modifiable determinants contributing to overweight and obesity. School policy and program environments that promote healthier behaviours might be one way to enhance student learning and achievement while reducing BMI (Kafatos, Manios, & Moschandreas, 2005; Katz, O'connell, Nijke, Yeh, & Nawaz, 2008).

The school environment is a common site for interventions related to health promotion and chronic disease prevention (Budd, 2006). School-based strategies have the potential to reach the vast majority of youth by providing similar services for all youth in the places that they spend more than half of their waking hours. While some initiatives to re-shape the school environment have been successful at modifying risky behaviours in youth, such as tobacco and drug use (Lee, 2011), there are yet no consistent or validated methods for schools to reduce the prevalence of overweight and obesity of their students (Harris, Kuramoto, Schulzer, & Retallack, 2009). The Centers for Disease Control and Prevention developed obesity prevention guidelines for schools that promote physical activity and healthy eating through comprehensive programs, policies, curricula, and education. For example, the core components of comprehensive school-based physical education (PE) are: 1) an increase in minutes of PE; 2) the inclusion of moderate or vigorous activity in PE class; 3) specification of PE teacher certification or professional development; 4) inclusion of environmental enhancements (physical facilities, equipment); and 5) adaptation of interventions to specific target populations (Brownson, Chriqui, Burgeson, Fisher, & Ness, 2010). Advocates and stakeholders invested in school health in Canada and internationally suggest that a Comprehensive School Health (CSH) approach is the most important and effective way to shape student health behaviours and behavioural outcomes (Veugelers & Schwartz, 2010). This internationally recognized framework addresses student health in a planned, integrated, and holistic way encompassing the whole school environment through the (I) social and physical environment, (II) teaching and learning, (III) healthy school policy, and (IV) partnerships and services (Veugelers & Schwartz, 2010).

Although most studies found that only a small proportion of variability in BMI is accounted for by the school environment (O'Malley, Johnston, Delva, Bachman, & Schulenberg, 2007), any variation

has the potential to expose youth to a different set of rules, programs, and supportive environments. While some of these rules, programs, or supportive environments have positively influenced the health of children and youth (O'Malley, Johnston, Delva, Bachman, & Schulenberg, 2007; Veugelers & Fitzgerald, 2005), much of this research has been through randomized controlled trials (Luepker, et al., 1996), which are not practical or feasible for use in real-world school settings. Instead, natural experiments offer a unique opportunity to conduct research on the effectiveness of policy or program implementation (Cummins, Petticrew, Higgins, Findlay, & Sparks, 2005) and to guide program and policies that are context-dependent (Rychetnik, Frommer, Hawe, & Shiell, 2002; Ramanathan, Allison, Faulkner, & Dwyer, 2008) when implementation is not controlled by researchers. However, due to a lack of longitudinal data, it has been difficult to evaluate the effectiveness of any of these natural experiments in schools to date.

If school programs and policies can be changed to shift the distribution or modify BMI trajectories, then the effects across the population could be substantial (Rose, 1992). As such, this study aimed to examine if implementation of new school obesity-related policies, programs or practices are associated with a change in BMI trajectory among youth. By identifying features of school environments that might influence or change BMI, and by communicating these findings with the appropriate stakeholders (e.g., policymakers, school board representatives), modifications can be made to promote healthier school environments. Results of this research might contribute to the generation of practice-based evidence for school-based obesity prevention programming.

Methods

Design

The COMPASS Study (COMPASS) is a prospective cohort study (2012-2019) designed to collect hierarchical and longitudinal data from a large sample of secondary school students and the schools that they attend in Ontario and Alberta, Canada. Within COMPASS, longitudinal student- and school-level data are collected annually from purposefully sampled schools that agreed to use active-information, passive-consent parental permission protocols. Student-level data are collected annually using the COMPASS questionnaire (Cq). School-level data were also collected annually using the School Policies and Practices Questionnaire (SPP). A full description of the COMPASS host study and its methods is available online (www.compass.uwaterloo.ca) and in print (Leatherdale, et al., 2014). The COMPASS study received ethics approval from the University of Waterloo Human Research Ethics Committee, as well as review panels from all participating school boards.

Sample and Population

In total, 41 Ontario schools participated in the first three waves (Y_1: 2012-13, Y_2: 2013-2014, Y_3: 2014-2015) of COMPASS. In Y_1, a total of 12,061 Grades 9 and 10 students in 41 Ontario schools completed the Cq during class time on the day of the scheduled data collection. Students missing information on height (n=1,935), weight (n=2,239) [therefore missing BMI; n=3,125], or other covariates of interest (gender, race, grade, or spending money; n=137) were excluded from the sample. The BMI trajectories of these 9th and 10th grade students were tracked from baseline to Y_3 (2014-2015). As described elsewhere (Qian, Battista, Bredin, Brown, & Leatherdale, 2015), self-generated identification codes were used to link data sets for the three years and to create the longitudinal data set for analyses. Participant attrition, student absenteeism/refusal, and inability to link student surveys resulted in a final linked longitudinal sample of 4,951 students attending 41 Ontario schools. These students participated in at least Y_1 and Y_2, with some also participating inY_3 of the COMPASS Host Study.

Measures

Outcome– Body Mass Index (continuous)

Students reported their height (in meters) and weight (in kilograms) on the Cq in Y_1, Y_2, and Y_3, which were used to calculate BMI (in kg/m^2). The COMPASS BMI measure was validated in a sample of Grade 9 students from Ontario, Canada, and demonstrated substantial 1-week test-retest reliability (intraclass correlation [ICC] = 0.95) and concurrent validity with measured height and weight (ICC = 0.84) (Leatherdale & Laxer, 2013). For the purpose of this paper, BMI was considered as a continuous outcome measure to provide more nuanced information than BMI derived weight status categories (e.g., overweight, obese) over time (Ruel, Reither, Robert, & Lantz, 2010). Compared to the total sample, rate of missing BMI was higher in grade 9 (28%), female (26%) students than grade 10 (22%) or male (23.5%) students.

Exposure – School policies and programs

The School Policies and Practices Questionnaire (SPP) is a paper-based survey that is completed by the COMPASS school contact most knowledgeable about programs and policies offered by the school. The SPP collects data on the presence of, absence of, or changes to school programs, policies, and facilities that might be related to the health behaviours and outcomes measured in the Cq. School contacts reported on aspects of physical activity (e.g., presence of intramural or varsity sports programming) and healthy eating (e.g., breakfast programs, field trips to farmers' markets) program and policy environments. Completed SPPs were collected from the schools during school data collection, along with copies of policy handbooks and/or student agendas with relevant school policy

information. In some cases, SPP information was further supplemented by school and school board website scans for additional policy or program details, and through communication with the COMPASS knowledge broker assigned to the school (Thompson-Haile, Laxer, Ledgley, & Leatherdale, 2015). The Y_2 and Y_3 SPPs captured changes to school policies, programs, or resources reported on the baseline SPP.

For this study, modifications to the school policy or program environments were captured through changes identified on the Y_2 SPPs related to (I) increasing physical activity, (II) improving dietary behaviours, (III) a combination of both approaches (Gonzalez-Suarez, Worley, Grimmer-Somers, & Dones, 2009). The details provided by schools about their changes to programs and policies were somewhat limited, so any modifications to physical activity programs or healthy eating practices were coded as a "general program or practice change" and were examined in comparison to schools that had made no changes to their physical activity or healthy eating policies, programs, or practices. Specific modifications between Y_1 and Y_2 (26 unique changes) were also noted (see table 1 in Results) and examined individually, compared to a pooled sample of control schools (15 control schools).

Covariates and Control Variables

Sociodemographic characteristics and obesity-related health behaviours were measured at baseline (Y_1) using the Cq. Covariates considered in the analyses had been previously found to be associated with BMI and health behaviours in youth, and included students' self-reported gender (male, female), grade (9, 10), race (White, Aboriginal [First Nations, Métis, Inuit], other), and average weekly spending money ($0, $1-$20, $21-$100, more than $100, "I don't know") (Butler-Jones, 2008). Our analyses controlled for school setting (urban/rural status) and year. Urban and rural geographic status were defined by their population sizes; small urban with a population between 1,000 and 29,999, medium urban with population between 30,000 and 99,999, and large urban with a population of 100,000 or more. Rural areas were classified as those with populations less than 1,000 people.[6] Finally, our analyses controlled for student behavioural patterns that had been identified by a previous analysis. That analysis identified four clusters of dietary behaviour, substance use, sedentary behaviour, and physical activity (*Traditional School Athletes, Inactive Screenagers, Health Conscious, and Moderately Active Substance Users*) that were associated with BMI (Laxer et al., 2017).

[6] http://www.statcan.gc.ca/eng/subjects/standard/pcrac/2016/introduction

Statistical Analysis

All analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Descriptive statistics were calculated for the total sample. The presence (or absence) of school policies and programs at baseline and the modifications within schools were recorded. Schools were first grouped based on their modifications: (i) addition of a physical activity policy (yes or no); (ii) addition of a physical activity program (any versus none); (iii) addition of a healthy eating policy (yes or no); and (iv) addition of a healthy eating practice (any versus none). Schools were also coded to reflect specific interventions (which were extracted from the SPP) and were compared to schools that indicated no modifications to policies and programs (control). The specific modifications at each school and are presented in Table 8.

We used longitudinal clustered regression models via PROC MIXED to identify which aspects of the school environment were associated with BMI trajectory in youth. These models accounted for the clustered nature of the COMPASS data (students nested within schools) and the repeated measures of subject over years Y_1-Y_3 (Laird & Ware, 1982). This approach fits 3-level linear mixed effects models (level 1 - school; level 2 - students within schools; and level 3 - repeated BMI measures over time within students) (Laird & Ware, 1982). Models included a random intercept for school to account for clustering of students within schools and a random intercept for the subject to account for subject's BMI measures over years Y_1–Y_3. The predictor variables included (i) addition of policies related to physical activity or healthy eating (Models 1 and 2), (ii) addition of physical activity programs (Model 3), (iii) addition of healthy eating programs or practices between Y_1 and Y_2 (Model 4), and (iv) specific school changes (Model 5). In all models, we compared the aforementioned specific intervention schools to the control schools. An initial null model was fit to examine variability in BMI that could be attributed to the clustered nature of the data and to identify whether including the school-level was necessary. Although small, variability across the schools was significant – school was therefore included in all subsequent models. Models examined the impact of the predictor variable (i.e., policy, program, practice, or specific intervention), the change over time (year), and the impact of the intervention (intervention*year interaction term). This interaction term represents the magnitude of effect of the intervention in each of the schools on the BMI trajectory of students attending the intervention school from Y_1 to Y_3, compared to a similar student in the control schools. All models examined predictors on BMI trajectory, considering BMI and time (year) as continuous. In addition to the school-level predictors, the final model included student level characteristics (sex, grade, race/ethnicity, weekly spending money, and typical behavioural patterns), school area (urban/rural status), and year.

Results

Variable descripives

At Y_1, 23.3% of youth were either overweight or obese, with an average BMI of 21.3 (±3.4) kg/m^2 (females 20.9 [±3.1] kg/m^2 and males 21.7 [±3.6] kg/m^2). Approximately half of the students were female (52.5%), a large majority were White (75.9%), and just over half of students were in grade 10 (52.3%). Only 20% of students were considered to be *health conscious* based on previous research, whereas nearly half of students (44.9%) engaged in high amounts of screen time and low levels of physical activity (*inactive screenagers*) (Laxer, et al., 2017). Average BMI only varied slightly across the schools, with discrepancies between the maximum and minimum BMI increasing annually (Y_1: 2.51 kg/m^2, Y_2: 3.12 kg/m^2, Y_3: 3.73 kg/m^2). This information is presented in Table 19 in Appendix G.

COMPASS School and neighbourhood characteristics

Just over half of participating COMPASS schools were in large urban areas (51.2%), while only two of the 41 schools were in rural areas, and the remaining schools were classified as small or medium urban. At baseline, only 25% of schools had a physical activity policy in place, and although mandated in 200, only 51.2% of schools indicated having a healthy eating policy (P/PM 150: School Food and Beverage Policy – a policy providing guidelines to schools about the types of food allowed and not allowed for sale in both the cafeteria and vending machines). The programs and practices most frequently reported by administrators included varsity sports (all 41 schools), events that promote physical activity (38 schools), programs to understand nutrition (40 schools), and cooking classes (38 schools). Programs and practices offered least to students included gardening (15 schools), and partnerships with local fitness facilities (20 schools).

Table 7. Overall and specific school-level changes from baseline to Y2 of the COMPASS Study (Number of schools=41)

Intervention #	Healthy eating policy	Healthy eating practice	Physical activity policy	Physical activity program	Intervention details
1	0	1	0	1	Messages promoting positive body image Healthy living week Improvements to breakfast program
2	0	1	0	1	Additional intramurals Healthy living week Healthy eating practice change (details not provided)
3	0	1	0	1	Gardening New health-in-action team Rock climbing, fishing, camping added as non-competitive sports
4	0	1	0	1	Increased number of days offering breakfast program Additional events to promote physical activity (Terry Fox Run, Jump Rope for Heart, Walk-a-thon) FUEL – Females Using Energy for Life program promoting physical activity and healthy eating in girls
5	1	1	0	1	FUEL – Females Using Energy for Life program promoting physical activity and healthy eating in girls New healthy eating policy (no details) Additional intramurals
6	0	1	0	1	Field trips to grocery stores Nutrition and veggie blitz Grant to build and outdoor basketball court; grant to provide salad bar Strengthened relationship with public health
7	0	1	0	1	Free hot lunches from Food and Nutrition classes once/week Fresh fruit and vegetable bags available around school as healthy snacks Snack bar offers smoothies and popcorn, meeting the guidelines Removed vending machines Added a weight room club
8	0	1	0	1	Enhanced breakfast program Promote activity throughout the day (cross-curricular) School offers “gym-blasts” Increase intramurals and outdoor education classes
9	0	1	0	1	Additional programs for healthy eating/foods program/after-school cooking classes Fresh fruit always available for students Gym open at lunch for basketball

10	0	1	1	1	Cooking classes in both semesters, students prepare healthy food for themselves and the whole school (once/week) School works with community agencies to promote positive self-image Snack program offered in the mornings Grant to build new fitness facility
11	0	1	0	1	Field trips to grocery stores and gardening opportunities to a small group of students Addition of baseball as a spring intramural
12	0	0	1	1	Promote intramurals at lunch Spirit events involve mandatory fitness challenges Trying to improve physical education for grade 9 students
13	0	1	0	1	Guest speaker from "seed to seed" to talk about locally grown and genetically modified food Intramurals and outdoor club offered New sports teams added
14	0	1	1	1	Increased nutrition education Cycle for mental health, Hoop-it-Up (and other special events) No details on the physical activity policy
15	1	1	0	1	Allow water in classroom and library Increased Public Health engagement on a Healthy Schools team Student focused running club
16	0	0	0	1	Additional intramurals Cheerleading Healthy mind and spirit week Walk to raise awareness for bone marrow registry
17	0	1	0	1	Breakfast program 5/days per week Science classes provide more training on nutrition Pilgrimage, Relay-for-Life, Rankin Cancer Run
18	1	1	0	1	Farm-to-caf initiative at the school Student involvement in cafeteria revitalization project Mental health initiative placing emphasis on healthy body image Re-introduction of intramurals
19	0	0	0	1	New partnership with local pool, providing access during non-instructional times
20	1	1	0	0	Stricter guidelines enforced in the cafeteria New breakfast club
21	0	0	0	1	Increased varsity programs Cancer walk Grade-9 activity day
22	1	1	1	1	Student-run cafeteria that offers healthier food options Classes to teach students about healthy eating and food preparation

					Daily intramurals, Healthy Huskies Walk (20 minutes for the entire school once/week) Fitness club for staff and students
23	0	1	0	1	Fitness centre open daily after school (mostly for varsity sports players) More opportunities for students to seek assistance/guidance for eating disorders and healthy body image
24	0	0	0	1	After-school fitness class Monday to Friday open to all students and staff
25	1	0	0	0	No details provided
26	0	1	0	0	Cooking classes
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
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C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	
C	0	0	0	0	

* C denotes a control school – for the models, all control schools were pooled to make comparisons

Between Y_1 and Y_2, 24 schools made at least one modification related to physical activity (policies or programs), while 21 schools made at least one modification to their healthy eating environments. A larger proportion of these were changes to programs or practices (81.1%) rather than to policies. Some schools indicated changes to physical activity (4 schools) or healthy eating (6 schools) policies, but the actual policy modifications made were unclear. Nine schools initiated programs or practices that might be considered as more "comprehensive," targeting more than one health behaviour and involving the whole school. For example, Intervention #2 included a "healthy living week that promoted physical activity, fruit and vegetable consumption, and reduced screen time. The 26 specific interventions examined in relation to BMI trajectories can be found in Table 7. Only one participating school made modifications related to all four dimensions (physical activity and healthy eating policy and program), which might be suggestive of a more comprehensive approach.

Model estimates

Table 8 presents the effect estimates, standard errors, and 95% confidence intervals (CI) for Models 1-4, while Table 9 presents the effect estimates, standard errors, and 95% confidence intervals for Model 5. The covariates associated with each of the five models are presented in Table 8. Results in Table 8 suggest that across Models 1-4 students that were male, in Grade 10, or those classified as *inactive screenagers* or *moderately active substance users* had steeper BMI trajectories than their counterparts. Furthermore, students attending schools in medium urban, small urban, and rural neighbourhoods had steeper BMI trajectories than students living in large urban neighbourhoods. Additionally, these results suggest BMI trajectories of students attending schools that added a new physical activity policy or healthy eating policy were not significantly different from those attending control schools. Results from Models 2 and 4 suggest that students attending schools that added a new physical activity program or healthy eating program/practice were significantly different from students attending control schools ($\beta = +0.07$ kg/m^2). While this may seem negligible, on a large scale and with a large number of students, could have a meaningful impact over time.

Table 8. Parameter estimates (estimating BMI trajectories) for schools implementing new physical activity and healthy eating policies (grouped) compared to schools that did not, among 4,951 Grades 9 and 10 students participating in three years of COMPASS (2012/13 to 2014/15) (N=41)

Parameter	**Model 1: Addition of physical activity policy**		**Model 2: Addition of physical activity program**		**Model 3: Addition of healthy eating policy**		**Model 4: Addition of healthy eating practice**	
	β (SE)	**95% CI**	**β (SE)**	**95% CI**	**β (SE)**	**95% CI**	**β (SE)**	**95% CI**
Intercept	20.11 (0.17)	19.77-20.46	20.14 (0.19)	19.76-20.52	20.08 (0.17)	19.73-20.42	20.14 (0.18)	19.78-20.50
Modifications to the school	0.01 (0.06)	-0.12-0.13	0.07 (0.03)	0.001-0.13	0.01 (0.05)	-0.09-0.11	0.07 (0.03)	0.001-0.13
Covariates								
School Location								
Large urban (ref)								
Medium urban	0.68 (0.20)**	0.28-1.07	0.69 (0.20)**	0.29-1.09	0.63 (0.21)**	0.23-1.04	0.69 (0.20)**	0.29-1.10
Small urban	0.63 (0.16)**	0.32-0.94	0.62 (0.16)**	0.31-0.93	0.64 (0.16)**	0.33-0.96	0.63 (0.16)**	0.32-0.94
Rural	1.67 (0.43)**	0.82-2.52	1.68 (0.44)**	0.83-2.54	1.71 (0.44)**	0.86-2.56	1.69 (0.44)**	0.83-2.55
Student-level factors								
Gender								
Male	1.03 (0.09)**	0.84-1.21	1.02 (0.09)**	0.84-1.21	1.019 (0.09)**	0.84-1.20	1.02 (0.09)**	0.84-1.21
Female (ref)					--			
Race/ethnicity								
White (ref)					--			
Aboriginal	0.46 (0.34)	-0.20-1.13	0.47 (0.34)	-0.19-1.13	0.47 (0.34)	-0.19-1.13	0.47 (0.34)	-0.19-1.13
Other	0.00 (0.12)	-0.23-0.23	0.00 (0.12)	-0.23-0.22	-0.01 (0.12)	-0.23-0.22	0.00 (0.12)	-0.23-0.22
Grade								
9 (ref)					--			
10	0.41 (0.09)**	0.22-0.59	0.41 (0.09)**	0.23-0.59	0.41 (0.09)**	0.23-0.60	0.41 (0.09)**	0.23-0.59
Spending money								
None (ref)					--			
$1 to $20	-0.03 (0.13)	-0.28-0.23	-0.03 (0.13)	-0.28-0.23	-0.03 (0.13)	-0.28-0.23	-0.03 (0.13)	-0.28-0.23
$21 to $100	0.01 (0.14)	-0.27-0.29	0.01 (0.14)	-0.28-0.29	0.01 (0.14)	-0.28-0.29	0.01 (0.14)	-0.28-0.29
More than $100	0.08 (0.22)	-0.36-0.51	0.07 (0.22)	-0.36-0.51	0.07 (0.22)	-0.36-0.50	0.08 (0.22)	-0.36-0.51
I do not know	-0.15 (0.17)	-0.48-0.18	-0.15 (0.17)	-0.48-0.18	-0.15 (0.17)	-0.48-0.18	-0.15 (0.17)	-0.48-0.18
Behaviour cluster								
Health conscious (ref)					--			
Inactive	0.35	0.10-	0.34	0.10-	0.35	0.11-	0.34	0.10-

Screenagers	(0.12)**	0.59	(0.12)**	0.59	(0.12)**	0.59	(0.12)**	0.59
Moderately Active Substance Users	0.75 (0.21)**	0.35-1.15	0.75 (0.21)**	0.34-1.15	0.750 (0.21)**	0.35-1.15	0.75 (0.21)**	0.34-1.15
Traditional School Athletes	0.20 (0.14)	-0.06-0.47	0.20 (0.14)	-0.07-0.47	0.21 (0.14)	-0.07-0.47	0.20 (0.14)	-0.07-0.47

* p<0.05 ** p<0.001

~We also examined the effect of (i), (ii), (iii), and (iv) in the same model as well as their cumulative effect (sum of all programs/policies) – this did not significantly predict a difference in BMI trajectories.

Table 9. Parameter estimates (estimating BMI trajectories) for each individual school physical activity program or healthy eating practice (intervention) compared to the pooled sample of control schools (N=41) in 4,951 grade 9 and 10 students participating in three years of COMPASS (2012/13 to 2014/15)

Parameter	**β (SE)**	**95% CI**
Intercept	20.23 (0.22)	19.74-20.72
Time	--	
School:		
1	0.05 (0.11)	-0.15-0.26
2	0.06 (0.09)	-0.11-0.23
3	0.22 (0.10)*	0.01-0.42
4	-0.07 (0.09)	-0.26-0.11
5	0.11 (0.12)	-0.14-0.35
6	0.10 (0.09)	-0.07-0.27
7	0.03 (0.12)	-0.21-0.27
8	0.34 (0.21)	-0.08-0.75
9	0.10 (0.13)	-0.16-0.35
10	0.14 (0.20)	-0.25-0.53
11	0.54 (0.20)**	0.14-0.94
12	0.16 (0.11)	-0.05-0.37
13	0.05 (0.18)	-0.29-0.40
14	0.02 (0.13)	-0.23-0.28
15	-0.02 (0.12)	-0.25-0.21
16	-0.08 (0.09)	-0.25-0.08
17	-0.16 (0.11)	-0.38-0.05
18	0.28 (0.12)*	0.04-0.51
19	-0.01 (0.11)	-0.23-0.21
20	-0.23 (0.29)	-0.80-0.34
21	-0.03 (0.09)	-0.24-0.20
22	-0.02 (0.11)	-0.24-0.20
23	0.40 (0.16)*	0.09-0.70
24	0.43 (0.19)*	0.06-0.80
25	-0.04 (0.10)	-0.23-0.15
26	-0.03 (0.12)	-0.26-0.20

Notes: controlling for school location, gender, race/ethnicity, grade spending money, and behaviour cluster.
* p<0.05 ** p<0.001

Table 9 results suggest that intervention schools of type 3 (β=0.22 kg/m^2 [95% confidence interval 0.01-0.42]), 11 (β=0.54 kg/m^2 [0.14-0.94]), 18 (β=0.28 kg/m^2 [0.04-0.51]), 23 (β=0.40 kg/m^2 [0.09-0.70]), and 24 (β=0.43 kg/m^2 [0.06-0.80]) were significantly different from the control schools. Intervention schools of type 3 added gardening, started up a new health-in-action team, and initiated some new non-competitive sports (i.e., rock climbing, fishing, and camping). Between baseline and Y_2, school 11 started to offer field trips and gardening opportunities to a small group of students at the school, and added a new intramural (baseball). School 18 began a farm-to-cafeteria initiative at the school, included students in their cafeteria revitalization project, emphasized healthy body image, and re-introduced intramural programs. Intervention schools of type 23 offered increased access to their fitness centre (daily after school), but mostly for students participating in varsity sports, and offered additional opportunities for students to seek assistance for eating disorders and healthy body image. Finally, intervention schools of type 24 offered interested students and staff an after-school fitness class Monday-to-Friday. Results from these models suggested that students attending those five schools had slightly faster-rising BMI trajectories after modifications to their school environments, compared to students attending control schools, while controlling for all meaningful covariates. The changes in average BMI across all intervention schools compared to the pooled sample of control schools can be found in Figure 9. Students attending intervention schools had similar or larger changes in BMI than students attending control schools.

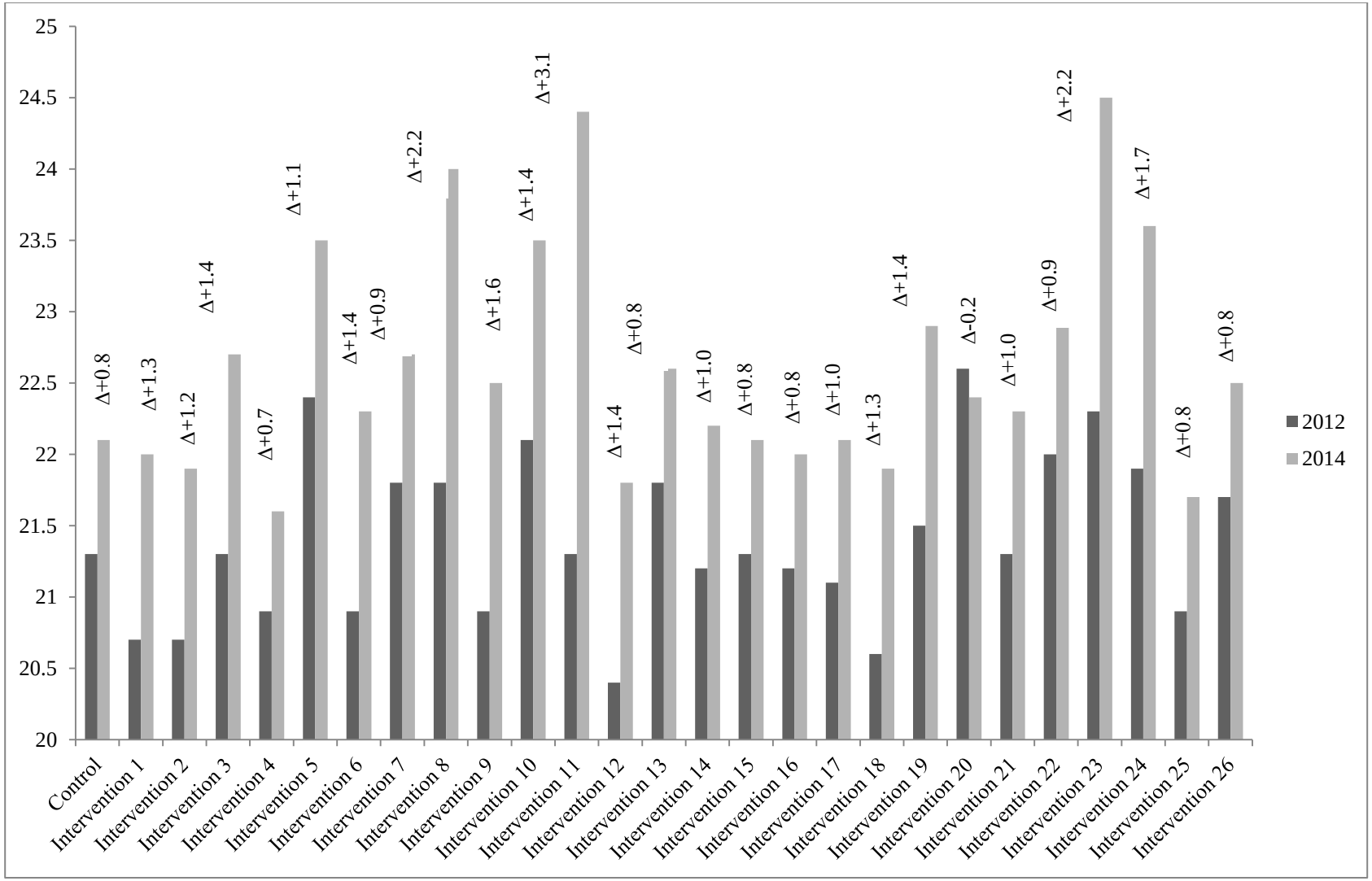

Figure 9. Changes in BMI from baseline (2012-2013) to Y3 (2014-2015) of COMPASS for the pooled sample of control schools and each individual "intervention" school

Discussion

This study examined how changes to obesity-related school policies, programs, and practices in the domains of physical activity and healthy eating were associated with BMI trajectories of Grades 9 and 10 students over three years in Ontario, Canada. While the majority of COMPASS schools had existing physical activity and nutrition programs and policies in place, after one year of COMPASS, more than half of the schools had made modifications to their physical activity or healthy eating environments. The changes to school policy, program, or practice environments related to overweight and obesity did not have an effect on slowing BMI trajectories, and some may appear to have had a detrimental effect by speeding the BMI trajectories of youth in some schools. It was encouraging, however, that schools did attempt to modify their environments in an effort to improve student health behaviours. The next step is to identify the programs and policies that are actually effective, and to recommend those to schools.

Comprehensive School Health (CSH) has been identified as a potentially effective approach to address overweight and obesity within schools (Veugelers & Schwartz, 2010). Despite this potential to improve student health behaviours and outcomes, CSH approaches are rarely put into practice (Deschesnes, Martin, & Jomphe-Hill, 2003). Considering that schools in this sample of COMPASS did not appear to use the CSH approach recommended by experts in school and youth health (i.e., CDC, WHO, school health networks, Ophea, etc.), this may explain the lack of evidence of effectiveness. Rather, using data from this large longitudinal sample of youth, we found that when schools implemented a series of individual, uncoordinated, and short-term obesity-related programs or policies in the domains of either diet or physical activity promotion, their effect on BMI trajectories over time was negligible. The effects of the single, simple programs, practices, and even policy changes were not sufficient to impact or attenuate youth's BMI trajectories. In some cases, they actually appeared to be more harmful. Moving forward, there is a need to implement and evaluate the impact of more coordinated, evidence-based, and structured comprehensive programs within schools.

Research on CSH lends the notion that although there are different interpretations and applications of CSH in schools, the one consistency is that CSH should follow a "school-based" approach and encompass a broad range of activities that form an integrated whole (Deschesnes, Martin, & Jomphe-Hill, 2003). Evidence from the APPLE schools program tailored to elementary school settings in Alberta has demonstrated the effectiveness of a comprehensive school health approach to target obesity-related health behaviours and BMI (Fung, et al., 2012). In that exemplary CSH study, the researchers found that children and youth are at lower risk of obesity when exposed to school-based interventions related to both diet and physical activity (Coleman, et al., 2005), and that the involvement

of the broader school community (family and community members) could increase the effectiveness of such interventions (Schwartz, Karunamuni, Veugelers, 2010). The success of the CSH depends on partnerships, engaging teachers, students, parents, and community members (Stokes & Mukherjee, 2000), none of which were identified in the COMPASS schools in this study.

Although a promising approach to health promotion, many school-based programs to date, including the ones in this study, have not had a significant effect on BMI. Rather, the results of this study suggested that some school initiatives may have been associated with an increased BMI trajectory. According to Baranowski's Mediating-Moderating Variable Model, it is possible that modifications to the school environment led to improvements in health behaviours that, over time, would lead to changes in BMI (Budd, 2006; Cook-Cottone, Casey, Feeley, & Baran, 2009; Baranowski, et al., 2000). Perhaps this can be explained by an incongruity between what schools offer and what students perceive to be available or what their preferences are. For example, while all participating COMPASS schools offered students varsity sports, and the majority offered intramural and other non-competitive sports, only 47% of youth in COMPASS report meeting the physical activity guidelines of 60 minutes of physical activity daily (Leatherdale, 2015). Taking a CSH approach in schools has the potential to offer healthy environments to all students through a variety of programs and policies that are intended to target the entire school population. It might be such that the programs and policies identified in this study were more targeted (i.e., a school that offered field trips to grocery stores and gardening opportunities to a small group of students at the school); these types of interventions might be important to evaluate among targeted populations, such as youth with different weight control intentions (i.e., those reporting actively trying to lose or gain weight).

Evaluations of natural experiments in schools on youths' behaviours and BMI have been mixed (Cullen & Watson, 2009; Fung, McIsaac, Kuhle, Kirk, & Veugelers, 2013; Madsen, 2011; Mendoza, Watson, & Cullen, 2010). Implementation of a new food policy in schools led to an increase in the proportion of youth meeting recommendations for fruit, vegetables, and milk after implementation of a new food policy in schools (Mendoza, Watson, & Cullen, 2010; Mullally, et al., 2010). On the other hand, for each additional food practice allowed in schools (e.g., use of food as incentive/reward, in-classroom fundraising using food), researchers identified an increase in BMI of 0.1 kg/m^2[7] (Kubik, Lytle, & Story, 2005). Two jurisdictions have seen opposite effects of collecting annual student BMI measurements in an effort to provide parents with information about their child's risk (Madsen, 2011; Ryan, Card-Higginson, McCarthy, Justus, & Thompson, 2006), with a reduction in Arkansas (Ryan et al., 2006) but not in California (Madsen, 2011). These differences might be attributable to the

[7] In the original paper, the authors interpreted these findings as a 10% change in BMI for each additional food practice in the school. We believe this to have been an oversight in the interpretation

implementation fidelity of the intervention, or the evaluation itself (Wang & Steward, 2013). If not following a comprehensive approach, students would be better served by high quality, well implemented program or policy interventions than multiple policies or programs implemented in a mediocre fashion. Evaluation of natural experiments is often limited, as it is difficult to infer possible causation without the necessary longitudinal data. For example, in one of the studies, the impact of the policy change was investigated using different cohorts of students, and comparing the average BMI and eating behaviours (Fung, McIsaac, Kuhle, Kirk, & Veugelers, 2013); information only useful for identifying trends. Although we did not identify any effective programs or policies in this study, COMPASS is uniquely positioned to evaluate similar natural experiments in schools moving forward in a cost-effective and efficient, yet scientifically robust manner by following the same students as they progress through school and are exposed to the changing school environment (Petticrew et al., 2005; Ramanathan, Allison, Faulkner, & Dwyer, 2008).

Strengths and Limitations

There are several limitations to this study. First, the programs and policies investigated were intended to target physical activity and/or healthy eating, and not specifically BMI. That said, it is possible that policy and program implementation led to changes in student health behaviours that, if sustained over time, could lead to a change in BMI (Baranowski, Anderson, & Carmack, 1998). Schools are more interested in designing programs and policies to target health behaviours, and are often not focused specifically on BMI (Kropski, Keckley, & Jensen, 2008). This has been seen in previous research, in which programs designed to increase physical activity or improve dietary behaviours were found to be successful at doing so, but had limited impact on weight status (Luepker, et al., 1996). Changes to BMI directly attributable to changes to health behaviours, or adopting healthier behaviours, might require more than two years of follow-up (Ewing, Brownson, & Berrigan, 2006; Wang & Steward, 2013). Second, the SPP is not a validated tool, and may not have captured the full school program or policy environment. Program and policy data were collected from the SPP, and specifically from the details provided by the administrator responsible for COMPASS within their school. While additional details on policy and program modifications were collected via the COMPASS knowledge broker, it is possible that some of these data were not fully complete, or that the reported modifications did not target those students at risk. Third, this study only considered the within school policy, program, and practice environments, and not area or school-level socioeconomic status, which is an important determinant of both individual and population health. This might be important to incorporate in future studies, since environmental interventions are often less intensively implemented in low-income school districts because of fewer teachers, less resources, and less funding. Fourth, in

our first set of models, schools that modified policies and programs related to the same health topic were grouped and coded as a general policy or program/practice change related to physical activity or healthy eating. This method does not provide a contextual understanding of the specific changes and processes in schools and instead assumes that programs and policies were implemented consistently across schools; however, it provided a larger number of schools with which to compare to the control schools and thereby increasing power. To try to understand and make conclusions about the school environment and its influence on BMI, it is important to have a contextual understanding of the schools and the specific changes they are making. Although this information was available and somewhat complete, this study may not have been sufficiently powered to provide significant or conclusive results for the individual and specific interventions. Future studies that are adequately powered should explore these types of interventions further across all grades.

Despite these limitations, this study has some notable strengths. First, we identified that, despite limited resources and evidence-based recommendations, schools are making an effort to modify their environments to improve student health behaviours. Already existing policies and programs already might facilitate and further promote healthier behaviours in schools. COMPASS is the first longitudinal study to examine how modifications to the school environment can influence BMI trajectories. It is possible that, with longer follow-up, and by tracking changes to dietary and physical activity behaviours (along the causal pathway to BMI), we might find valuable information to develop and implement more effective school obesity-related policies and programs. Second, although we did not identify significant changes to BMI trajectories by school-level factors, this study has provided important baseline information for future studies. As recommended by Baranowki and colleagues, anthropometric measures of height and weight are critical for surveillance and epidemiologic research – needed next are programs and policies with enough follow-up time to capture an outcome (Baranowski, et al., 2000). Third, this study has highlighted a need for both an ecological approach, and specifically CSH, to target BMI in schools. Researchers and school stakeholders interested in targeting BMI might be more successful if they implement school-based strategies that target multiple behavioural determinants across the broader school environment. Finally, although the results of this study were not statistically significant or suggested that some programs and policies might negatively impact on BMI trajectories, it is possible that with a larger number of schools and a longer follow-up time, we might find something more meaningful.

Conclusions

Education systems are uniquely positioned to influence student health behaviours in ways that might slow the progression of unhealthy weight gain among youth. In order to do so, schools need the

empirical evidence to plan, guide, and implement policy, programming, and intervention efforts. Although the results of this study did not support it, there is still precedence for schools to take a multifaceted and comprehensive approach to obesity prevention through policies and programs that can improve nutrition, physical activity and other risky health behaviours (Pyle, Sharkey, Yetter, Felix, & Furlong, 2006). With more detailed and comprehensive information collected from schools, adequate follow-up time and a sufficient sample of COMPASS schools, we may identify evidence of effective school-based interventions with potential to produce resources and strategies that can be rapidly disseminated to other COMPASS schools. Further research and evaluation on policies and programs, including implementation fidelity and outcome evaluation, is recommended.

Chapter 7:
General Discussion

Overview

There is a need to identify effective population health interventions to improve health behaviours and reduce overweight and obesity in children and adolescents (Katz, 2009). And specifically, these potential solutions should be considered in light of their contexts to best address some of the underlying conditions that might be contributing to systematic differences in health status at the population level (Shoveller, Viehbeck, Di Ruggiero, Greyson, Thomson, & Knight, 2016). Context should not just be controlled for, rather must be well understood before implementing and assessing effectiveness of interventions. The purpose of this dissertation was to explore important and unanswered questions about some of the factors that contribute to overweight and obesity, as well as some of the potential predictors of BMI trajectories in youth. The three main objectives were to (1) understand how modifiable health and risk behaviours cluster, and how the clustered behavioural patterns are related to overweight and obesity in youth; (2) investigate how behavioural clusters predict BMI trajectories and whether or not there were differences in the BMI trajectories across the behavioural clusters; and (3) explore how changes to obesity-related school policies and programs predict BMI trajectories among youth. Key findings, implications, and future research directions from the three dissertation manuscripts are presented in this section.

Summary of Key Findings

The results from the first manuscript in Chapter 4 laid the foundation for the subsequent studies by identifying distinct behavioural clusters among youth that were each differentially associated with overweight and obesity. Using latent class analysis, this manuscript identified that youth in the baseline sample of COMPASS belonged to one of four distinct behavioural classes, each characterized by different combinations of risky behaviours: *Traditional School Athletes, Inactive Screenagers, Health Conscious,* and *Moderately Active Substance Users*. Youth belonging to the *Traditional School Athlete, Inactive Screenager,* or *Moderately Active Substance User* clusters were significantly more likely to be overweight or obese compared to youth in the *Health Conscious* group. This study was unique from other studies on behavioural clusters in youth, since it considered other risky behaviours in which youth engage that might partially contribute to an increase in BMI, such as binge drinking and marijuana use.

Chapter 5 (manuscript two) examined the effect of youths' membership in a particular behavioural cluster on their BMI trajectories. Understanding that cluster membership was associated with concurrent weight status, as evidenced in Chapter 4 through cross-sectional analyses, I was

interested in identifying the effect of belonging to a behavioural cluster on BMI over time, and in providing some evidence for causality using the longitudinal data. Although I had hypothesized that behavioural clusters would predict differential trajectories among youth, results suggested a consistency of BMI trajectories, independent of the behavioural cluster to which the students belonged. It was not surprising that BMI increased across all four behavioural clusters annually; what was unexpected, however, was that each of the clusters increased by the same amount, and that the differences across the clusters were not statistically significant. Although not hypothesized, these findings still have important implications, and suggest that there might be some common behaviours across the clusters that are leading to similar BMI trajectories, such as low fruit and vegetable consumption, or that behaviours not typically shown to be associated directly with obesity, such as binge drinking, might require more attention (Battista & Leatherdale, 2017). Figure 16 in Appendix F shows how, if all youth continued to engage in the behaviours that identified their cluster membership, the average BMI in each cluster would "cross over" into overweight or obese categories, although some clusters would do so earlier than others. Some challenges and limitations faced with this particular manuscript are described in the *Limitations* section below.

Chapter 6 (the third manuscript) intended to build on the findings from the first and second manuscripts by exploring how changes to school policy and program environments affect BMI trajectories in youth, while taking into consideration the different behavioural clusters. Youth health researchers, particularly those interested in population health and prevention within the school environment, suggest the importance of a Comprehensive School Health (CSH) approach. Using a quasi-experimental approach to observe naturally-occurring changes to the school environment, I identified that none of the COMPASS schools were employing a true CSH approach at the time the data were collected, but were rather modifying their school environments through short-term, unfocused, non-comprehensive policies or programs in single behavioural domains. These non-comprehensive and behaviourally focused school interventions were not effective at modifying or improving BMI trajectories in youth. Rather, the majority of interventions investigated did not have any meaningful effect on BMI trajectories among youth, and some were found to potentially be more harmful, speeding the trajectories of BMI in youth.

Thus, my hypotheses from the second and third manuscripts were not supported. This does not mean that the findings are not important; rather, they offer opportunities for further investigation and potentially, de-implementation of some of the newly implemented programs for further evaluation. For example, it is possible that the behavioural clusters identified in the first manuscript do not predict BMI trajectories, but that instead, youths' BMI is a predictor of the behaviour patterns and therefore cluster membership (Patrick, et al., 2004). Overweight or obese youth are less likely to participate and engage

in physical activity for fear of stigmatization or discomfort around their peers (Gray, Janicke, Ingerski, & Silverstein, 2008). Overweight and obese youth might also be more likely to engage in higher amounts of screen-time activity, as well as other risky behaviours such as marijuana use and binge drinking, instead of engaging in physical activity with their peers (Farhat, Iannotti, & Simons-Morton, 2010; Leatherdale, Wong, Manske, & Colditz, 2008). Future research might consider this, and examine behavioural patterns using latent class analysis, stratified by weight status. In the third manuscript, the policies and programs implemented in COMPASS schools, while intended to target the entire school population, may not have been reaching the appropriate students. There tends to be variable uptake and adoption of new programs and policies in schools and similar community-based interventions, dependent on a number of factors that were not controlled for in the analyses, such as competing time, other interests or priorities, or funding constraints (Durlak & Dupre, 2008). It is important to note that many of the policies cited by schools were mandated at the provincial level or drawn directly from the curriculum (Hunter, Leatherdale, Storey, & Carson, 2016), which are different than policies designed and enforced within the school, and relevant to the school-specific context. It is also important to note that consideration was not given to the built environment surrounding the schools, or to the physical structures within the school, which could both influence student health behaviours and BMI trajectories. Recreation facilities or food retail outlets within close proximity to the school might seem more appealing than what is available to students within the school setting. Further, school programs offered to students may not be well attended if the facilities in which they are held are not safe, accessible, or inviting. For example, outdoor intramurals would not be appealing to students if the school grounds are not well maintained or safe.

Cumulatively, the research in this dissertation contributes to furthering our current understanding of overweight and obesity among Ontario's youth, although the implications for policy are not clear. There is evidence of an association between behavioural cluster membership and overweight and obesity, although the temporality of this association is still not clear. The *Inactive Screenagers, Traditional School Athletes,* and *Moderately Active Substance Users* were at greater risk of overweight and obesity, and had higher BMIs at baseline than the *Health Conscious* clusters, but their BMI trajectories were the same. These results do make it difficult to recommend concrete actions. I had hypothesized that some clusters would have a higher slope when modeled with time as an interaction term, which would suggest behaviours and clusters to target earlier than others. This was not identified, and rather, the results indicate that all clusters might benefit from some attention, which would be made possible by targeting all youth through CSH approaches. Results also indicate the possible effectiveness of earlier interventions among younger children, which might ameliorate some of the negative outcomes associated with overweight and obesity.

The recommendation for a CSH approach, and other wide reaching interventions, is grounded in theory but not yet well supported by real-world evidence (CDC, 2013; Domitrovich, et al., 2008). To obtain evidence of effectiveness, such interventions must be tested through natural experiments and quasi-experimental methods (Craig, Katikireddi, Leyland, & Popham, 2017; Craig, et al., 2012). The National Institutes of Health have provided some suggestions for interventions that might be successful at preventing obesity, and natural experiments to test their success, including (1) investments in transportation infrastructure to increase active transportation; (2) changing the food environment to improve eating behaviours, (3) economic policies (tax subsidies) to make the healthier choices the easier choice, (4) changes to organizations (schools)**,** and (5) changes in health care systems related to obesity prevention (Pratt, Stevens, & Daniels, 2008). If implemented, the challenges associated with evaluating such natural experiments include incomplete development of interventions, lack of standardization of study designs, data collection methods, and statistical approaches (Craig, et al., 2012). Although COMPASS schools have the best of intentions for their students, evidenced by their voluntary participation in a study that aims to improve student health behaviours, many COMPASS administrators do not complete the SPPs with sufficient detail for researchers to evaluate the impact of specific interventions. While completing the SPP is a requirement of the study (Leatherdale, et al., 2014), the level of detail required on the SPP is not specified and is therefore not consistent across schools. The SPP also does not include definitions for "policies," "programs," or "practices," which might increase the inconsistencies across reporting. It is difficult to conclude with certainty that "interventions" were implemented as intended, and therefore might find difficulty in evaluating and making recommendations. Without both practice- and evidence-based interventions, it is difficult for schools to develop appropriate or targeted interventions for their students (Brownson, Fielding, & Maylahn, 2009).

Overall Strengths of the Dissertation

There are several strengths to this dissertation. First, the use of a large population-based longitudinal cohort study in the three manuscripts is a strength. Although the final samples used in the two manuscripts with the linked longitudinal data were larger than most (n~5,000) used in previous school-based research, the number of schools was not high (N=41). Since COMPASS is an ongoing study that has recruited additional schools and students in subsequent years, there are many opportunities for similar research questions to be addressed in the future, using larger samples of students from more schools. Another strength of this dissertation was the inclusion of health behaviours frequently found to be associated with BMI in addition to other risk behaviours that emerge in adolescence, such as smoking, marijuana use, and binge drinking. This was both novel and informative,

and can have important implications in future research on youth and obesity, during youths' transition into early adulthood and when they begin to gain more autonomy. Another major strength of this dissertation was the use of complex and contemporary statistical approaches throughout the dissertation, including latent class analysis (manuscript 1) and hierarchical multi-level modeling in manuscripts 2 and 3. Fourth, the use of BMI as a continuous measure (manuscripts 2 and 3) is a strength, and is unlike much of the research in this field; public health research is usually cross-sectional and often uses a categorical measure of BMI to simplify interpretability. This categorization has a cost in terms of the ability to detect relationships between predictors and outcomes. Since I did not hypothesize finding large changes in youths' BMI that would lead to a categorical shift in weight status, the use of a categorical measure of BMI would have underestimated the effect estimate and led to a misrepresentation of the association between predictor variables and BMI. Instead, the use of BMI as a continuous measure in this case was more informative (Ruel, Reitner, Robert, & Lantz, 2010). Had results been significant, I could have made suggestions based on the magnitude of the change in BMI and BMI trajectories, thereby highlighting which behavioural clusters were most "unhealthy," or which interventions were most successful at changing the trajectories of BMI in youth.

Other strengths of this dissertation include its breadth and complexity, the use of a variety of study designs, and that multiple levels of influence of the socio-ecological model were considered. It is also the first longitudinal study of youth health in Canada to examine the influence of the school environment on BMI trajectories of youth, and the first study in Canada to consider other risk-related substance use behaviours in latent class analyses to examine how they factor into behavioural patterns and their association with BMI among a large sample of Ontario high school students. It is also one of only few studies that focused on secondary school students and the high school environment, as most research is focused on elementary or middle-school aged youth. The research questions were novel, and had potential to set benchmarks to target behavioural improvements in youth. The findings from this research provided valuable insight to inform future development, tailoring, and targeting of school-based prevention initiatives to where they are most likely to have an impact, mostly supporting the need for researchers to take an increasingly CSH approach. Finally, my involvement with the COMPASS Study from its inception, including working directly with schools as a Knowledge Broker and witnessing first-hand some of the modifications made to the school environment is a strength in that it allowed me to better understand the data and some of the contexts in which interventions are developed and implemented.

Overall Limitations of the Dissertation

It is important to make note of several limitations of this dissertation research. The first manuscript in this dissertation was cross-sectional, but intended to "set the stage" for the rest of the dissertation. Temporality, or whether the behavioural patterns precede youths' overweight or obesity cannot be determined using results from a cross-sectional study. Consequently, the second manuscript could not make causal inferences regarding the relationship between these health behaviour clusters and BMI because of null findings. The purpose of the second manuscript was to identify if belonging to a behavioural cluster at baseline was associated with BMI trajectories. Limitations of that manuscript included disregarding the possibility of youth changing behaviours and therefore not remaining in their predicted behavioural cluster. If shifting behavioural clusters, then the relationship between baseline cluster and BMI trajectories would be unclear. A methodological limitation of the third manuscript was the absence of true control groups – although control groups are not as important for natural experiments as they are for randomized controlled or pragmatic trials (Craig, Katikireddi, Leyland, & Popham, 2017; Craig, et al., 2012; Ramanathan, Allison, Faulkner, & Dwyer, 2008). This means that some schools may have improperly completed their SPPs, or made modifications that were left unreported, misclassifying them as control or intervention schools. However, the control groups used for this study were likely as clean as a randomized controlled trial could be and sufficient for school-based research. Future studies might consider matching intervention and control schools for specific school characteristics, such as size, urban/rural status, and sociodemographics. Further to this, I only examined the policy and program environments in the third manuscript. Schools may have made modifications to their physical environments that may have contributed to a change in health behaviours or BMI (Nichol, Pickett, & Janssen, 2009) – which may have contaminated the analyses for this study.

A major limitation of the overall dissertation is that the measures for both exposure and outcome were self-reported. Many of these measures are prone to information biases, including recall and social desirability bias, which means that there could be potential for misclassification of both exposure and outcome. Evidence suggests that physical activity is over-reported and poor eating behaviours are underreported due to a desirability to present socially accepted behaviours. This misreporting is likely to be non-differential; thus, if properly reported, the associations between latent classes and weight status may have been even greater than found in the research. In Chapter 4, youth may have under-reported their risky behaviours, which would have either assigned them to a different latent class, or contributed to the creation of different latent classes in general. In Chapters 4-6, youth may have misreported their height and weight, mostly through under-reporting (Leatherdale & Laxer,

2013). This would have led to an underestimation of the effect. However, it is likely that if youth under-reported their height or weight, they might be expected to have similarly under-reported in subsequent years (Black & Cole, 2001), and therefore, misreporting would have remained consistent and would only have been a problem for the first manuscript. While there are limitations with self-reported measures, the measures of BMI, physical activity, dietary intake, and sedentary behaviour were all validated using a sub-sample of students in the COMPASS study (Leatherdale & Laxer, 2013; Leatherdale, Laxer, & Faulkner, 2014).

Some potentially relevant confounding variables were unaccounted for in the regression analyses in all three manuscripts. For example, in Chapter 6, Manuscript 3, it might have been useful to consider school size or socioeconomic status, two factors that influence prioritization, planning, and implementation of new programs or policies, as well as the types of policies or programs that schools choose to implement (Estabrooks, Lee, & Gyurcsik, 2003; O'Malley, Johnston, Delva, Bachman, & Schulenberg, 2007; Domitrovich, et al., 2008). Something else to consider in future research is the organizational culture of the school, and whether or not the school considers obesity to be a problem, and then whether the school prioritizes it as a problem they wish to target with programming or policy changes (Stamatakis, Leatherdale, Marx, Yan, Colditz, & Brownson, 2012). This alone may impact schools' decision to target overweight and obesity as a priority (Stamatakis, Leatherdale, Marx, Yan, Colditz, & Brownson, 2012). Further, parents, siblings, and peers may influence health behaviours or BMI (Field, Camargo, Taylor, Berkey, Roberts, & Colditz, 2001). Parents' weight status is significantly associated with child's weight status, and social networks can influence health behaviours and even BMI status (Christakis & Fowler, 2007).

Many researchers note the inherent problems with using BMI as a measure of overweight and obesity, and that it is perhaps not the most appropriate indicator for particular populations. In Chapter 4 and 5, BMI for the *Traditional School Athletes* group was similar to the *Inactive Screenagers*, but their body compositions are likely to be very different, with higher muscle mass for the *Traditional School Athletes* and higher fat for the *Inactive Screenagers*. Losing weight might have different implications for the two groups (Flegal, Tabak, & Ogden, 2006); for the athletes, reducing their BMI might be associated with a loss in muscle mass, which would not be recommended and is rather a counterproductive message to send to these youth, if we are trying to encourage youth to be more physically active.

Although COMPASS was not designed as a representative study of youth in Ontario, a limitation of this dissertation is an inability to generalize the findings to all youth. Despite this, results from the first manuscript identified similar behavioural patterns to previous research that was based on a more representative sample of youth in other countries, and results of the third manuscript

corroborated others' conclusions that a CSH approach might be ideal for targeting BMI and its related health behaviours (Fung, et al., 2012; Veugelers & Schwartz, 2010).

The analyses in the third manuscript might have been subject to exposure measurement error by including any intervention related to physical activity or healthy eating as an intervention, under the assumption that these programs might impact BMI. Similarly, since some schools did not provide details about all of their interventions, it is possible that some interventions were underrepresented. All of the school-level measures were based on quantity or availability as reported by the school administrator, with no information on quality or accessibility to students. Knowing just the presence of physical activity resources, or modifications to healthy eating environments, does not provide any indication on suitability for youth, or whether or not youth perceive the availability of such resources within the school (Scott, Evenson, Cohen, & Cox, 2007). This measure also suffered from the assumption that all students attending schools that implemented new policies or programs were similarly exposed, introducing potential exposure misclassification, since the schools that youth attend are not necessarily the only environment in which their physical activity or dietary behaviours are influenced (French, Story, & Jeffery, 2001). School interventions may have many uncontrollable factors that contribute to the heterogeneity of intervention implementation (including the differences in interventions themselves), such as community involvement, school context, financial support, and school uptake/buy-in, none of which were reported or considered in the analyses. This study was intended to identify the effect of changing the environment over time, and not examine the presence or absence of policies and programs at baseline (refer to Appendix G for these results). That said, it is possible that control schools had existing initiatives in place that were effective at promoting health behaviours and healthy weights, and did not require any changes (Hunter, Leatherdale, Storey, & Carson, 2016). Similarly, as is the case in most natural experiments, there was no true control group of students considered to be "not exposed" to any obesity-related health intervention (Craig, Katikireddi, Leyland, & Popham, 2017). Because of this, it was challenging to design and build the appropriate models to examine the association between school environment and BMI trajectories. Though not surprising, the standard deviations for the behavioural clusters' BMIs overlapped; had any of the results been significant, it would have been difficult to draw any conclusions or make recommendations that would not (potentially) equally harm one group while benefiting another.

Although the largest to date, this dissertation was still limited by the small sample size (41 schools) (Snijders, 2005; Craig, et al., 2012), and may have been underpowered to detect an effect (Lissau, 2007) – since COMPASS has grown in subsequent years, future research could answer similar questions using a larger number of COMPASS schools. The largest limitation of this dissertation research, however, was the use of BMI as an outcome measure, instead of health behaviours, which

would have been (1) possibly feasible to change over two-to-three years, and (2) along the continuum between the intervention and the overall, later outcome of BMI (Bauman, Sallis, Dzewaltowski, & Owen, 2002; Baranowski, Anderson, & Carmack, 1998). Additionally, many of the interventions were likely designed with the intent of improving behaviour, and not focusing on the outcome of BMI (Sharma, 2006). Evidence of effectiveness is not as strong if the focus is on a distal health outcome such as BMI/overweight/obesity, but instead must focus on the more immediate or proximal factors, such as health behaviours (Baranowski, Anderson, & Carmack, 1998). Interventions may appear to be more effective if they consider measuring mediating variables, such as physical activity and dietary behaviours, instead of just BMI or other anthropometric outcomes (Baranowski, Anderson, & Carmack, 1998).

Future studies may consider examining changes to health behaviours after similar modifications are made to the school environment. BMI is also a measure that is often missing in research, more than measures of physical activity and sedentary behaviour, and perhaps more than some dietary behaviours. This was overcome by using an available case analysis in the three studies, assuming data were missing at random. Future studies might consider data imputation of BMI for a more full sample, or again, focusing on health behaviour outcomes.

Implications for Public Health

Promoting physical activity, improving dietary behaviours, and reducing overweight and obesity are public health priorities (Visscher & Seidell, 2001). Although the relationships observed in this dissertation between the school environment and BMI were either negligible or opposite to what was hypothesized, potential implications are still high given the opportunities available for public health. For example, each study alluded to (a) need for additional research, but also (b) the need for more extensive policies and comprehensive programs that can address BMI in youth. Knowing the ways in which behaviours cluster in youth (manuscript 1), and though not significant, that particular clusters might reach overweight or obesity more quickly than others (manuscript 2), schools, in partnership with public health, should consider designing comprehensive programs and policies that follow a CSH approach to target those particular behavioural clusters. This might include assistance from public health to secure additional funding for schools to implement and effectively evaluate more CSH approaches (Piercy et al., 2015), or public health working collaboratively with schools on such comprehensive school programs as Ophea's Healthy Schools Certification (https://www.ophea.net/healthy-schools-certification). Public health nurses could also provide schools with additional resources or links to organizations in the community to help in their efforts to change behaviours or reduce overweight and obesity. For example, the Healthy Kids Resource Centres, funded

by the Ministry of Health and Ministry of Education, can provide training, tools, webinars, and consultations related to healthy eating (Nutrition Resource Centre: http://www.opha.on.ca/What-We-Do/Programs/Nutrition-Resource-Centre.aspx) and physical activity (Physical Activity Resource Centre: http://parc.ophea.net/). Public health units across Ontario have strong links to these resource centres, and could make use of their services in schools.

Use of Natural Experiments for Public Health

Government agencies are beginning to recognize the importance of natural experiments, the use of quasi-experimental methods to evaluate large population health interventions, and the implementation of new policies or programs within the school setting, where randomized controlled trials are not feasible (Craig, Katikireddi, Leyland, & Popham, 2017). Although natural experiments can contribute to the evidence of effectiveness of policy interventions, they have been underused for public health and in school-based research. Natural experiments can play an important role in identifying effective interventions (Petticrew, et al., 2005), and are particularly useful for policy-makers and public health, since their efficacy is based on and leads to an unbiased evaluation of policy or program implementation. More specifically, in this context, evaluation of natural experiments using a quasi-experimental design is a popular method for public health, as it is more feasible, acceptable, and appropriate for evaluating health interventions where there is no defined control or intervention group. Their limitations, however, lie in their inability to directly determine causality (Dunning, 2008). In a systematic review of naturally occurring experiments by Mayne, Auchincloss and Michael (2015), authors suggest that policies and built environment changes can be promising ways to target obesity prevention efforts, evaluated through natural or quasi-experimental methods. Authors reviewed 37 studies, 18 of which focused on nutrition, 17 on physical activity, and three on body mass index. Overall, they found that nutrition-related interventions were more effective when they included banning or restricting unhealthy food, mandating the offering of healthier foods, and altering payment rules with food vouchers. Physical activity interventions were more effective when they included changes to active transportation infrastructure and included longer follow-up. The only effective intervention on BMI was one that included the installation of a light rail system (Mayne, Auchincloss, & Michael, 2015).

Some might consider one other underutilized method to implement and evaluate school-based programs or policies – pragmatic trials. Pragmatic trials lie on the continuum which can provide more evidence on the effectiveness of an intervention than randomized controlled trials, but not as much as natural experiments. However, pragmatic trials are more controlled than natural experiments, providing evidence on the adoption of an intervention in real-world clinical practice (Ford & Norrie, 2016).

Implications for School health

To date, researchers have been unable to provide schools with concrete, evidence-based effective obesity prevention strategies, since intervention components and the environments in which they have been implemented vary considerably (Katz, 2009). Studies have shown that schools are making improvements to their environments in ways that make them increasingly conducive to adopting and maintaining healthy behaviours (Story, Nanney, & Schwartz, 2009). In a meta-analysis evaluating the effectiveness of school-based programs on the prevention and management of childhood obesity, school-based intervention programs protected youth from overweight and obesity compared to those in control schools in the short term (Gonzalez-Suarez, Worley, Grimmer-Somers, & Dones, 2009). While longer-running programs tended to be more effective than shorter programs (Gonzalez-Suarez, Worley, Grimmer-Somers, & Dones, 2009), there is still not enough evidence of effectiveness, with these studies concluding that additional research is required to assess longer-term effectiveness.

As highlighted in Chapter 6, those health researchers and other public health practitioners generally push for a CSH approach (Veugelers & Schwartz, 2010), and that the more comprehensive and complex an intervention, the more successful it will be (Michie, van Stralen, & West, 2011). This approach aligns well with the socio-ecological model (SEM), and the likelihood of greater intervention effectiveness when addressing all levels of this SEM (Sallis, Bauman, & Pratt, 1998). Some commonly mentioned modifications include the need for schools to implement stronger policies to provide healthier food to students in schools, and to limit student access to unhealthy foods during the school day (Story, Nanney, & Schwartz, 2009; Foster, et al., 2008). Schools should also offer additional programming to increase both the frequency and duration of physical activity (Story, Nanney, & Schwartz, 2009). The challenge, however, is that schools are tasked with so many competitive priorities and the expectation that they will implement multiple programs targeting multiple risk behaviours.

It is plausible to increase the amount of physical activity and to improve the types of food that students are exposed to during the school day. The Ontario Ministry of Education only mandates one credit course in health and physical education over the four years of secondary school[8]. Other jurisdictions have greater physical activity requirements for students – in Manitoba, students must obtain four high school physical education credits, and in British Columbia, students are expected to participate in a minimum of 150 minutes of physical activity weekly[9]. To address physical inactivity and overweight/obesity among elementary students in Ontario, the Ministry of Education implemented a policy targeting daily physical activity, where school boards were required to provide all elementary students with a minimum of 20 minutes of sustained moderate-to-vigorous physical activity each

[8] (http://www.edu.gov.on.ca/eng/ curriculum/secondary/health9to12.pdf)
[9] http://www.auditor.on.ca/en/content/annualreports/arreports/en13/2013ar_en_web.pdf

school day, during instructional time. The implementation of this policy, *Daily Physical Activity in Elementary Schools, Grades 1-8* (PPM/138)[10] was supported by teacher resource guides, e-learning modules, ideas for fun activities, and funding to purchase athletic equipment. A similar policy has not yet been developed or implemented in Ontario secondary schools, but might be one potential opportunity to increase and promote physical activity to reduce the risk of overweight and obesity. Related to healthy eating, however, the Ontario Ministry of Education implemented a new *School Food and Beverage Policy* (PPM 150), across all 72 school boards in the province in September 2011. In conjunction with the Ontario Government's commitment to make schools healthier, PPM 150 was designed with the intent to improve educational, attitudinal (e.g., food preferences and eating behaviours) and health-related outcomes through the application of nutritional standards on which foods to sell most, less, or not at all.

We must at first distinguish between the ultimate goal of policies and programs, especially as they pertain to the school environment. Policies in schools should be designed and implemented with desired end result of creating a health-promoting school, while programs should be the link between the health promotion policy and the priorities of the school (Sacks, Swinburn, & Lawrence, 2009). Policies can be enacted and created by schools, school boards, or the Ministry of Education. For example, PPM 138 and PPM 150 described above were mandated by the government and all schools were legally required to comply. With this in mind, schools might consider establishing policies first, and then developing creative interventions that are contextually relevant but also related to the policy to promote behavioural policies. Youth are more likely to feel support through policies, administrative commitment, and positive staff role modeling, and to engage in any related programming that supports the policies (Kubik, Story, & Davey, 2007). In a study by Kubik and colleagues, they found that there was discordance between administrator-reported policies and practices, with practices being more prevalent than policies. This may be explained by principals' tendencies to over-report healthy school practices, or schools not recognizing the importance of policies to enhance healthy, consistent, and sustainable practices across the school environment (Kubik, Lytle, Farbakhsh, Moe, & Samuelson, 2009).

In addition to lacking evidence on effective school-based obesity prevention programming, schools sometimes cite budgetary constraints, time limitations, space, and other obligations as barriers to implementing CSH programs (Dwyer, Allison, Barrera, Hansen, Goldenberg, & Boutilier, 2003; Winson, 2008; Lissau, 2007). Anecdotally, schools participating in the COMPASS Study have indicated some of the challenges faced when implementing PPM 150, particularly related to reduced

[10] http://www.edu.gov.on.ca/extra/eng/ppm/138.html

revenue from students purchasing food from off-school property. Implementing programs is sometimes viewed as consuming time that should be allocated to academic endeavours. However, education and health should not be viewed in silos, since a physically and emotionally healthy student is more likely to succeed academically (Penedo & Dahn, 2005; Veugelers & Schwartz, 2010). By developing a more thorough model or framework that is both comprehensive and systematic, researchers and policy makers can better understand prevention of chronic diseases that can be achieved through environmental and policy approaches (Brownson, Haire-Joshu, & Luke, 2006). By targeting overweight and obesity in youth, particularly in the school setting, there is potential to reduce the future onset of overweight and obesity, thus reducing the medical costs and burden associated with obesity and related complications.

Based on some reviews on obesity prevention and intervention among school-aged youth, interventions are more likely to be effective if they:

- involve parents, family, and the wider community (Kehm, Davey, & Nanney, 2015; Khambalia, Dickinson, Hardy, Gill, & Baur, 2012) to assist in transferring behaviour change from the school environment to the home environment;
- are designed to be culturally sensitive (Story, Evans, Fabsitz, Clay, Holy Rock, & Broussard, 1999);
- include effective staff training and sustainability (Katz, 2009);
- use participatory activities and training in behaviour techniques or coping skills (Katz, 2009);
- are done in collaboration with community programs or facilities (Dobbins, De Corby, Robeson, Husson, & Tirilis, 2009);
- target both physical activity and healthy eating (Khambalia, Dickinson, Hardy, Gill, & Baur, 2012; Brown & Summerbell, 2009);
- include modifications to the school environment to improve nutritional quality of school foods (Waters, et al., 2011; Katz, 2009);
- include modification to the school physical activity environment to increase physical activity throughout the school week (Ribeiro, et al., 2010);
- are set in environments that support healthy eating and physical activity, combining education with modifications to the school environment (Waters, et al., 2011);
- involve teachers and other specialists focusing on physical activity or healthy eating (Cook-Cottone, Casey, Feeley, & Baran, 2009; Waters, et al., 2011);
- are longer in duration (Zenzen & Kridli, 2009; Cook-Cottone, Casey, Feeley, & Baran, 2009);
- integrate into the school curriculum (Gonzalez-Suarez, Worley, Grimmer-Somers, & Dones, 2009; Roseman; Brown & Summerbell, 2009); and
- consider multiple school contexts (Morton, Atkin, Corder, Suhrcke, & van Sluijs, 2015).

Directions for future research

Future research is required to build upon the findings of this dissertation. Overall, the results from this dissertation pointed to specific areas for future research and resources, including more robust study designs that include measures both pre- and post-policy and program implementation, especially for those that would require longer follow-up time to make note of changes to health behaviours and

health outcomes (Budd & Volpe, 2006). Knowing the total length of the program/school intervention, not just the follow-up time, is also important; long term effectiveness in both BMI and behaviour change might be dependent on the length or duration of the intervention (Jaime & Lock, 2009). Having additional insight into how health behaviours cluster together in unique ways to influence BMI and BMI trajectories, and identifying if these clusters remain the same over time might assist in the development of more targeted interventions. Similarly, more precise measures of the school environment, obtained directly through the SPP and Knowledge Broker communications, may be worthwhile. The SPP has been updated for future COMPASS data collections in response to some of the methodological challenges and limitations mentioned above. This research could be further enhanced using case studies, where modifications to the school environment are carried out with COMPASS Knowledge Brokers, incorporating a component of evaluation from inception through to completion (both process and outcome evaluation) (Khambalia, Dickinson, Hardy, Gill, & Baur, 2012). While this may be time-consuming, it could provide a more accurate depiction of the school environment and the level of exposure of the student population. Further, Knowledge brokers could work directly with schools, using a more integrated knowledge translation approach, similar to the APPLE Project and their use of a school health facilitator (Fung, et al., 2012). This would be best accomplished by engaging with schools through the process of implementation, beginning with setting the priority and establishing which behaviours and health outcomes are most important to target Knowledge brokers can work with the schools from the beginning through to implementation, monitoring, and evaluation (Leatherdale, et al., 2014); without appropriate monitoring, there are no consequences for schools that fail to comply with Ministry mandated policies, or for schools that do not reach the appropriate students through their programming, leading schools to revert and return to their comfortable practices (Bulter & Allen, 2009). When a policy is mandated, schools may have more existing support, such as documents that provide clear and concise standards, or a resource guide to help guide implementation, monitoring, and evaluation. However, if policy is not valued or prioritized, then its implementation will undoubtedly be hindered (Lucarelli, et al., 2014). One study found that in the US, districts have strong wellness policies that are not implemented to full-scale at the school-level; on the other hand, when schools are cautious about committing to written policies from a higher-level, but have their own supportive practices in place to promote healthy behaviours, they are more effective (Larson, Davey, Hoffman, Kubik, & Nanney, 2015).

It is important to recognize that the short follow-up time post-schools' interventions may have impacted our ability to detect a significant change or difference in BMI trajectories. Future COMPASS research should look for interventions that enable healthy environments and sustainable behaviour change that might lead to a subsequent reduction in BMI. This can be facilitated by evaluations of

school-based interventions using a quasi-experimental study design, with pre- and post-intervention comparison and control groups. The impact of these interventions on obesity-related lifestyle behaviours should later be evaluated, rather than just focusing on BMI (Baranowski, Anderson, & Carmack, 1998). Although not investigated in this dissertation, it is a strength of the COMPASS Study in general that there are repeated measures on youth pre- and post-interventions (if appropriately implemented) in both intervention and control settings; such longitudinal follow-up in the same youth is often not possible when evaluating such population health interventions. There is a need for evaluation – according to the EPODE methodology, it is a key-driver for policy-makers, and can foster mobilization of stakeholders in a more systematic and sustainable way (Borys, et al., 2012).

Despite the growing research on the school environment and the importance of the CSH Approach, there is still a lack of consistency in how these are measured, interpreted, and their effect on behaviours and BMI. In built environment research, there are low levels of agreement between objective and perceived measures of the neighbourhood built environment, which might be true of school environments as well. It might be important to consider questions in the COMPASS Student questionnaire that collect information on student perceived support from their schools to be physically active or to eat healthily. If discrepancies exist between the SPP measures and what youth perceive, there are opportunities for public health and school administrators to work collaboratively to bridge the gap between what the school offers and what the students perceive to be available in the schools (Scott, Evenson, Cohen, & Cox, 2007).

Future school-based and other behavioural research might benefit from incorporating more complex measures when evaluating the environment, the use of audit tools, following specific conceptual models and theories including the EnRG Framework (Kremers, De Bruijn, Visscher, Van Mechelen, De Vries, & Brug, 2006), the ANGELO Framework (Swinburn, Egger, & Raza, 1999), and the RE-AIM framework (Glasgow, Vogt, & Boles, 1999). Using these, researchers might better delineate which features of the school environment contribute most to behaviours and BMI to help inform interventions. More specifically, the notion of socio-ecological framework that there are multiple levels of influence affecting implementation quality of new programs or policies suggests the need to consider the macro-level factors (government, policy), school-level factors, and individual factors at play. There is a period between program/policy adoption and sustainability in schools (and effectiveness) – implementation – that should be assessed. This implementation quality measure bridges the gap between what was planned and intended to what was actually delivered through the intervention (Domitrovich, et al., 2008; Glasgow, Vogt, & Boles, 1999). It might be such that for systemic interventions to reach high implementation quality and result in desired effects, we would

need three to five years of school data (Domitrovich, et al., 2008). See Appendix H for an explanation of these frameworks.

Other areas for future research include latent transition analyses to examine if youth remain within their behavioural clusters or transition into different clusters (Collins & Lanza, 2013), and how these changes might be associated with BMI trajectories. Further, knowing the types of behaviours that tend to cluster, it might be worth disseminating such information to schools, and recommending that modifications to their environments be made that target multiple behaviours, and then evaluate if such modifications had an effect on health behaviours (rather than BMI). Ideally, future studies would also be of longer duration; however, only some have found that interventions implemented for more than one year led to a significant reduction in the odds of overweight or obesity (Gonzalez-Suarez, Worley, Grimmer-Somers, & Dones, 2009), while others did not. One other area to explore is the effect of school programs and policies on overweight/obese students, compared to normal weight students, and also the effect of baseline BMI status on the behavioural clusters (O'loughlin, Gray-Donald, Paradis, & Meshefedjian, 2000). For example, in a 5-week middle school-based obesity prevention intervention that implemented school-wide environmental changes, encouraged students to eat healthy school cafeteria foods, and included peer-led education and marketing, students in the intervention schools classified as obese at baseline had significant reductions in BMI percentile 2 years later (-2.33 percentiles) compared to control schools. This equaled to approximately nine fewer pounds of body weight expected after two years for obese students in the intervention schools, thus suggesting that school-based interventions might have long-term effects on BMI among those obese students (Bogart, et al., 2016).

By testing policy or program implementation in COMPASS schools, and following the process from start to finish, practitioners, policy-makers, and researchers will be able to collect the necessary information to translate into policy and effective school programming. This might be best accomplished using a setting-specific conceptual framework that focuses on both Comprehensive School Health and the socio-ecological model.

Summary of PhD research experience

The PhD candidate gained considerable research experience while completing her degree requirements and this dissertation research that led to a practice-oriented job at Public Health Ontario, where she is evaluating the implementation of a province-wide community-based obesity intervention. Using a critical lens, she summarized and appraised the literature in order to identify gaps and limitations of existing literature in order to design original research questions. To answer the questions, she designed appropriate epidemiological studies, and employed both novel and complex statistical techniques, which required management of complex and large datasets. The candidate was involved in

collecting primary data by participating in many COMPASS data collections, knowledge brokering for 5 years (carved the way for other knowledge brokers), and earlier on in the PhD, designed and conducted a qualitative research project (focus groups in schools) to identify student perceived barriers and facilitators to physical activity and healthy eating. For that project, the candidate was involved and led each step, beginning with a proposed research question, preparing and receiving ethics approval, preparing all of the necessary focus group documents (moderator guides, background questionnaires, and consent forms), recruiting schools, conducting focus groups, and qualitative analysis and dissemination. The candidate has been involved in COMPASS from the start in 2012, and chose to follow the schools from that year, feeling a very close connection to the data and many of the schools involved. She was also able to apply her skills (evaluation, knowledge brokering, quantitative and qualitative methodology) in her role as an evaluation consultant at Ophea, evaluating their Healthy Schools Certification program (a "Comprehensive" approach to improving students' health behaviours in schools). Although not examined in this dissertation, the candidate has considered and recommended etiological concepts for future research to answer similar questions, including effect modification or mediation. Finally, the candidate has disseminated research findings to different audiences, through peer-reviewed journals, and both academic and non-academic presentations.

Conclusions

Overweight and obesity in children and youth in Canada and worldwide is a public health concern that requires further research**.** The Government of Ontario has identified that population health interventions are needed to reverse the trend of childhood obesity and set children on a positive trajectory for lifelong health. Although the findings of this dissertation research were not sufficient to provide specific recommendations to schools, they support previous research and the Ministry of Education in the need for a Comprehensive School Health approach. By understanding the ways that risky behaviours cluster, the context in which poor health behaviours occur, and the potential impact of the school environment on shaping these behaviours and BMI, there is foundation upon which to base new policies and programs that will most effectively improve health behaviours and BMI of youth. The school environment offers a safe and inclusive environment in which to intervene, and COMPASS provides the necessary data to evaluate the effects of such interventions on behaviours and BMI. However, without clearly reported modifications or interventions in schools, and sufficient follow-up time to assess both proximal (behavioural) and distal (BMI) outcomes, it is challenging to make recommendations to schools on what works, in which settings, and in what context.

References

This section includes the references from all earlier chapters, presented by chapter. Reference formatting for the manuscripts matches the journals to which each manuscript was submitted.

Chapter 1: General Introduction

Bronfenbrenner, U. (2000). *The Ecology of Human Development: Experiments by Nature and Design.* Washington, DC: American Psychological Association.

CDC. (2013). *Make a difference at your school.*

Daniels, S., Arnett, D., Eckel, R., Gidding, S., Hayman, L., Kumanyika, S., et al. (2005). Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. *Circulation, 15*, 1999-2012.

Dietz, W., & Gortmaker, S. (2001). Preventing obesity in children and adolescents. *Annual Review of Public Health, 22*, 337-353.

Freedman, D., Khan, L., Serdula, M., Dietz, W., Srinivasan, S., & Berenson, G. (2005). The relation of childhood BMI to adult adiposity: the Bogalusa Heart Study. *Pediatrics, 115*(1), 22-27.

Janssen, I., Katzmarzyk, P., Boyce, W., King, M., & Pickett, W. (2004). Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *Journal of Adolescent Health, 35*, 360-367.

Katz, D., O'connell, M., Njike, V., Yeh, M., & Nawaz, H. (2008). Strategies for the prevention and control of obesity in the school setting: systematic review and meta-analysis. *International Journal of Obesity, 32*(12), 1780-1789.

Katzmarzyk, P. (2011). The economic costs associated with physical inactivity and obesity in Ontario. *The Health & Fitness Journal of Canada, 4*(4), 31-40.

Kropski, J., Keckley, P., & Jensen, G. (2008). School-based obesity prevention programs: an evidence-based review. *Obesity, 16*(5), 1009-1018.

McLeroy, K., Bibeau, D., Steckler, A., & Clanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly, 15*(4), 351-377.

Nanney, M., Nelson, T., Wall, M., Haddad, T., Kubik, M., Laska, M., et al. (2010). State school nutrition and physical activity policy environments and youth obesity. *American Journal of Preventive Medicine, 38*(1), 9-16.

Roberts, K., Shields, M., de Groh, M., Aziz, A., & Gilberta, J. (2012). Overweight and obesity in children and adolescents: results from the 2009 to 2011 Canadian Health Measures Survey. *Health Rep, 23*(3), 37-41.

Rose, G. (2008). *Rose's Strategy of Preventive Medicine.* Oxford: University Press.

Sjoberg, R., Nilsson, K., & Leppert, J. (2005). Obesity, shame, and depression in school-aged children: a population-based study. *Pediatrics, 116*(3), e389-92.

Whitaker, R., Wright, J., Pepe, M., Seide, K., & Dietz, W. (1997). Predicting obesity in young adulthood from childhood and parental obesity. *New England Journal of Medicine, 25*, 869-873.

WHO. (2008). School policy framework: implementation of the WHO global strategy on diet, physical activity and health.

Chapter 2: Literature Review

Aaron, D.J., Storti, K.L., Robertson, R.J., Kriska, A.M., & Laporte, R.E. (2002). Longitudinal study of the number and choice of leisure time physical activities from mid to late adolescence: implications for school curricula and community recreation programs. *Archives of Pediatrics and Adolescent Medicine, 156*(11): 1075-1080.

Allensworth, D.D. (1997). Improving the health of youth through a coordinated school health programme.
Journal of Education and Health Promotion, 4: 42-47.

Allensworth, D. D., & Kolbe, L. J. (1987). The comprehensive school health program: exploring an expanded concept. *Journal of school health*, *57*(10), 409-412.

Alamian, A. & Paradis, G. (2009). Clustering of chronic disease behavioral risk factors in Canadian children and adolescents. *Preventive Medicine, 48:* 493-499.

Baranowski T. Understanding the behavioral linkages needed for designing effective interventions to increase fruit and vegetable intake in diverse populations. J Am Diet Assoc. 2011;111(10):1472-1475.

Baranowski, T., Cullen, K. W., Nicklas, T., Thompson, D., & Baranowski, J. (2002). School-based obesity prevention: a blueprint for taming the epidemic. *American Journal of Health Behavior*, *26*(6), 486-493.

Battista, K., & Leatherdale, S. T. (2017). Estimating how extra calories from alcohol consumption are likely an overlooked contributor to youth obesity. *Health promotion and chronic disease prevention in Canada: research, policy and practice*, *37*(6), 194.

Baruth, M., Addy, C., Wilcox, S., & Dowda, M. (2011). Clustering of risk behaviours among African American adults. *Health Education Journal, 71*, 565-575.

Bere, E., & Klepp, K. (2004). Correlates fo fruit and vegetable intake among Norwegian schoolchildren: parental and self-reports. *Public Health Nutrition, 7*(8), 991-998.

Berkey, C.S., Rockett, H.R.H., Gillman, M.W., & Colditz, G. (2003). One year changes in activity and in inactivity among 10- to 15-year-old boys and girls: relationship to change in body mass index. *Pediatrics, 111*: 836-843.

Berkey, C. S., Rockett, H. R., Field, A. E., Gillman, M. W., & Colditz, G. A. (2004). Sugar-added beverages and adolescent weight change. *Obesity*, *12*(5), 778-788.

Berkey, C.S., Rockett, H.R.H., Field, A.E., et al. (2000). Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. *Pediatrics, 105* (E56).

Biddle, S.J., Gorely, T., & Marshall, S.J. (2009). Is television viewing a suitable marker of sedentary behavior in young people? *Annals of Behavioral Medicine, 38*: 147–153.

Biddle, S.J.H., Gorely, T., & Stensel, D.J. (2004). Health-enhancing physical activity and sedentary behaviour in children and adolescents. *Journal of Sports Sciences, 22*(8): 679-701.

Boarnet, M.G., Anderson, C.L., Day, K., McMillan, T., & Alfonzo, M. (2005). Evaluation of the California Safe Routes to School legislation – urban form changes and children's active transportation to school. *American Journal of Preventive Medicine, 28*: 134-140.

Bogden, J. F. (2000). Fit, Healthy, and Ready to Learn: A School Health Policy Guide. Part 1. Physical Activity, Healthy Eating, and Tobacco-use Prevention. *National Association of State Boards of Education.*

Boone, J.E., Gordon-Larsen, P., Adair, L.S., & Popskin, B.M. (2007). Screen time and physical activity during adolescence: longitudinal effects on obesity in young adulthood. *International Journal of Behavioral Nutrition and Physical Activity, 4*(26).

Boone-Heinonen, J., Gordon-Larsen, P., & Adair, L. S. (2008). Obesogenic clusters: multidimensional adolescent obesity-related behaviors in the US. *Annals of Behavioral Medicine, 36*(3), 217-230.

Briefel, R.R., Crepinsek, M.K., Cabili, C., Wilson, A., & Gleason, P.M. (2009). School food environments and practices affect dietary behaviors of US public school children. *Journal of the American Dietetic Association, 109*: S91-S107.

Bronfenbrenner, U. (2000). *The Ecology of Human Development: Experiments by Nature and Design.* Washington, DC: American Psychological Association.

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

Browning, H.F., Laxer, R.E., & Janssen, I. (2013). Food and eating environments of Canadian schools. *Canadian Journal of Dietetic Practice and Research, 74*(4): 160-166.

Brownson, R.C., & Jones, E. (2009). Bridging the gap: translating research into policy and practice. *Preventive Medicine, 49*: 313-315.

Bruner, M. W., Lawson, J., Pickett, W., Boyce, W., & Janssen, I. (2008). Rural Canadian adolescents are more likely to be obese compared with urban adolescents. *International Journal of Pediatric Obesity*, *3*(4), 205-211.

Burke, V., Beilin, L.J., Durkin, K., Stritzke, W.G.K., Houghton, S. & Cameron, C.A. (2006). Television, computer use, physical activity, diet and fatness in Australian adolescents. *International Journal of Pediatric Obesity, 1:* 248-255.

Butcher, K., Sallis, J.F., Mayer, J.A., & Woodruff, S. (2008). Correlates of physical activity guideline compliance for adolescents in 100 US cities. *Journal of Adolescent Health, 42*: 360-368.

Calle, E., & Thun, M. (2004). Obesity and cancer. *Oncogene, 23*(38), 6365-6378.

Carson, V., & Janssen, I. (2011). Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. *BMC Public Health, 11*(1), 274.

Casperson, C., Powell, K., & Christenson, G. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports, 100*(2), 126-130.

Cauchi, D., Glonti, K., Petticrew, M., & Knai, C. (2016). Environmental components of childhood prevention interventions: an overview of systematic reviews. *Obesity Reviews, 17*, 1116-1130.

CDC. (2013). *Make a difference at your school.*

CDC. Youth risk behavior surveillance – United States, 2009. MMWR 2010; 59 (no. SS-5).

Centers for Disease Control and Prevention (CDC. (2011). School health guidelines to promote healthy eating and physical activity. *MMWR. Recommendations and reports: Morbidity and mortality weekly report. Recommendations and reports/Centers for Disease Control, 60*(RR-5), 1.

Centers for Disease Control and Prevention (CDC 2000). Strategies for reducing exposure to environmental tobacco smoke, increasing tobacco-use cessation, and reducing initiation in communities and health-care systems. *Morbidity and mortality weekly report, 49*(NO RR-12)

Chinapaw, M. J. M., Proper, K. I., Brug, J., Van Mechelen, W., & Singh, A. S. (2011). Relationship between young peoples' sedentary behaviour and biomedical health indicators: a systematic review of prospective studies. *Obesity Reviews, 12*(7), e621-e632.

Chriqui, J., Resnick, E., Schneider, L., Schermbeck, R., Adcock, T., Carrion, V., & Chaloupka, F. (2013). School District Wellness Policies: Evaluating Progress and Potential for Improving Children's Health Five Years after the Federal Mandate. Brief Report. Volume 3. *Robert Wood Johnson Foundation*.

Coffield, J., Metos, J., Utz, R., & Waitzman, N. (2011). A multivariate analysis of federally mandated school wellness policies on adolescent obesity. *Journal of Adolescent Health, 49*(4), 363-370.

Cole, T., Bellizi, M., Flegal, K., & Dietz, W. (2000). Establishing a standard definition for childhood overweight and obesity worldwide: international survey. *British Medican Journal, 320*(7244), 1240-1243.

Cook-Cottone, C., Casey, C., Feeley, T., & Baran, J. (2009). A meta-analytic review of obesity prevention in schools: 1997-2008. *Psychology in the Schools, 46*(8), 659-719.

Collison, K.S., Zaidi, M.Z., Subhani, S.N., Al-Rubeaan, K., Shoukri, M., & Al-Mohanna, F.A. (2010). Sugar-sweetened carbonated beverage consumption correlates with BMI, waist circumference, and poor dietary choices in school children. *BMC Public Health, 10*(234).

Craig, C., Cameron, C., Russel, S., & Beaulieu, A. (2001). *Increasing physical activity: supporting children's participation [2000 activity monitor].* Ottawa, ON: Canadian Fitness and Lifestyle Research.

Craig, P., Cooper, C., Gunnell, D., Haw, S., Lawson, K., Macintyre, S., et al. (2012). Using natural experiments to evaluate population health interventions: new MRC guidelines. *J Epidemiol Community Health, 66*(12), 1182-1186.

Crespo, C.C., Smit, E., Troiano, R.P., Bartlett, S.J., Macera, C.A., & Anderson, R.E. (2001). Television watching, energy intake, and obesity in US children. *Archives of Pediatric & Adolescent Medicine, 155*(3): 360-365.

CSEPa. Canadian Society for Exercise Physiology, 2014: Canadian Physical Activity Guidelines for Youth – 12 to 17 years. HYPERLINK "http://www.csep.ca/CMFiles/Guidelines/CSEP-InfoSheets-youth-ENG.pdf" \t "externObjLink" http://www.csep.ca/CMFiles/Guidelines/CSEP-InfoSheets-youth-ENG.pdf (2014) [accessed February 21, 2015]

CSEPb. Canadian Society for Exercise Physiology, 2014: Canadian Sedentary Behaviour Guidelines for Youth – 12 to 17 years. HYPERLINK "http://www.csep.ca/CMFiles/Guidelines/CSEP_SBGuidelines_youth_en.pdf" http://www.csep.ca/CMFiles/Guidelines/CSEP_SBGuidelines_youth_en.pdf (2014) [accessed on February 21, 2015].

Daniels, S. (2006). The consequences of childhood overweight and obesity. *The future of children*, 47-67.

Davison, K. K., & Birch, L. L. (2001). Childhood overweight: a contextual model and recommendations for future research. *Obesity Reviews*, *2*(3), 159-171.

de la Haye, K., D'Amico, E.J., Miles, J.N.V., Ewing, B., & Tucker, J.S. (2014). Covariance among multiple health risk behaviors in adolescents. *Plos One, 9*(5).

De Bourdeaudhuij, I., Van Cauwenberghe, E., Spittaels, H., Oppert, J. M., Rostami, C., Brug, J., ... & Maes, L. (2011). School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project. *Obesity Reviews*, *12*(3), 205-216.

Diethelm, K., Jankovic, N., Moreno, L.A., Huybrechts, I., De Henauw, S., Vriendt, T. Gonzalez-Gross, M., Leclercq, C., Gottrand, F., Gilbert, C.C., Dallongeville, J., Cuenca-Garcia, M., Manios, Y., Kafatos, A., Plada, M., & Kersting, M. (2011). Food intake of European adolescents in the light of different food-based dietary guidelines: results of the HELENA study. *Public Health Nutrition, 15*(3): 386-398.

Dietz, W. (2004). Overweight in childhood and adolescence. *New England Journal of Medicine*, 855-857.

Doak, C.M., Visscher, T.L.S., Renders, C.M., & Seidell, J.C. (2005). The prevention of overweight and obesity in children and adolescents: a review of interventions and programmes. *Obesity Reviews, 7*: 111-136.

Dobbins, M., De Corby, K., Robeson, P., Husson, H., & Trillis, D. (2009). School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6-18. *Cochrane Database of Systematic Reviews.*

Driskell, M.M., Dyment, S., Mauriello, L., Castle, P., & Sherman, K. (2008). Relationships among multiple behaviors for childhood and adolescent obesity prevention. *Preventive Medicine, 46*: 209-215.

Dunning, T. (2005). Improving causal inference: strengths and limitations of natural experiments. American Political Science Association, Washington, DC.

Durant, N., Harris, S. K., Doyle, S., Person, S., Saelens, B. E., Kerr, J. Norman, G.J., & Sallis, J. F. (2009). Relation of School Environment and Policy to Adolescent Physical Activity. J*ournal of School Health, 79(*4), 153-159.

Dusenbury, L., & Hansen, W. B. (2004). Pursuing the course from research to practice. *Prevention Science, 5(*1), 55-59.

Ebrahim, S., Montaner, D., & Lawlor, D. (2004). Clustering of risk factors and social class in childhood and adulthood in British women's heart and health study: cross sectional analysis. *BMJ, 328*.

Elgar, F.J., Roberts, C., Moore, L., & Tudor-Smith, C. (2005). Sedentary behaviour, physical activity and weight problems in adolescents in Wales. *Public Health, 119*: 518-524.

Evans-Whipp, T., Beyers, J. M., Lloyd, S., Lafazia, A. N., Toumbourou, J. W., Arthur, M. W., & Catalano, R. F. (2004). A review of school drug policies and their impact on youth substance use. *Health Promotion International*, *19*(2), 227-234.

Falbe, J., Willett, W. C., Rosner, B., Gortmaker, S. L., Sonneville, K. R., & Field, A. E. (2014). Longitudinal relations of television, electronic games, and digital versatile discs with changes in diet in adolescents. *The American journal of clinical nutrition*, *100*(4), 1173-1181.

Farhat, T., Iannotti, R. J., & Simons-Morton, B. G. (2010). Overweight, obesity, youth, and health-risk behaviors. *American Journal of Preventive Medicine*,*38*(3), 258-267.

Faulkner, G. E., Buliung, R. N., Flora, P. K., & Fusco, C. (2009). Active school transport, physical activity levels and body weight of children and youth: a systematic review. *Preventive Medicine, 48*(1), 3-8.

Ferreira, I., van der Horst, K., Wendel-Vos, W., van Lenthe, F.J., & Brug, J. (2006). Environmental correlates of physical activity in youth – a review and update. *Obesity Reviews, 8*: 129-154.

Field, A. E., Gillman, M. W., Rosner, B., Rockett, H. R., & Colditz, G. A. (2003). Association between fruit and vegetable intake and change in body mass index among a large sample of children and adolescents in the United States. *International journal of obesity*, *27*(7), 821-826.

Flynn, M. A. T., McNeil, D. A., Maloff, B., Mutasingwa, D., Wu, M., Ford, C., & Tough, S. C. (2006). Reducing obesity and related chronic disease risk in children and youth: a synthesis of evidence with 'best practice' recommendations. *Obesity Reviews*, *7*(s1), 7-66.

Fontaine, K., & Barofsky, I. (2001). Obesity and health-related quality of life. *Obesity REviews, 2*, 173-182.

Foster, G. D., Sherman, S., Borradaile, K. E., Grundy, K. M., Vander Veur, S. S., Nachmani, J., Karpyn, A., Kumanyika, A., & Shults, J. (2008). A policy-based school intervention to prevent overweight and obesity. *Pediatrics*, *121*(4), e794-e802.f

Fox, M. K., Dodd, A. H., Wilson, A., & Gleason, P. M. (2009). Association between school food environment and practices and body mass index of US public school children. *Journal of the American Dietetic Association, 109*(2), S108-S117.

Freedman, D.S., Kettel Khan, L., Serdula, M.K., Ogden, C.L., & Dietz, W.H. (2006). Racial and ethnic differences in secular trends for childhood BMI, weight, and height. *Obesity Reviews, 14*:301-308.

French, S.A., Story, M., Neumark-Sztainer, D., Fulkerson, J.A., & Hannan, P.J. (2001). Fast food restaurant use among adolescents: associations with nutrient intake, food choices, and behavioural and psychosocial variables. *International Journal of Obesity, 25*: 1823-1833.

Fung, C., Kuhle, S., Lu, C., Purcell, M., Schwartz, M., Storey, K., & Veugelers, P. J. (2012). From "best practice" to "next practice": the effectiveness of school-based health promotion in improving healthy eating and physical activity and preventing childhood obesity. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 27.

Galan, I., Boix, R., Medrano, M.J., Ramos, P., Rivera, F., & Moreno, C. (2014). Individual factors and school-based policies related to adherence to physical activity recommendations in Spanish adolescents. *Prevention Science, 15*: 588-599.

Garaulet, M., Ortega, F.B., Ruiz, J.R., Rey-Lopez, J.P., Beghin, L., Manios, Y., Cuenca-Garcia, M., Plada, M., Diethelm, K., Kafatos, A., Molnar, D., Al-Tahan, J, & Moreno, L.A. (2011). Short sleep duration is associated with increased obesity markers in European adolescents: effect of physical activity and dietary habits. The HELENA study. *International Journal of Obesity, 35*: 1308-1317.

Garriguet, D., Janssen, I., Craig, C. L., Clarke, J., & Tremblay, M. S. (2011).*Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey*. Statistics Canada.

Giles-Corti, B., Timperio, A., Bull, F., & Pikora, T. (2005). Understanding physical activity environmental correlates: increased specificity for ecological models. *Exercise and Sport Sciences Reviews, 33*(4): 175-181.

Gonzalez-Suarez, C., Worley, A., Grimmer-Somers, K., & Dones, V. (2009). School-based interventions on childhood obesity: a meta-analysis. *American Journal of Preventive Medicine, 37*(5), 418-427.

Goodman, L. (2007). On the assignment of individuals to latent classes. *Sociological Methodology, 37*: 1-22.

Gordon-Larsen, P., Adair, L. S., & Popkin, B. M. (2002). Ethnic differences in physical activity and inactivity patterns and overweight status. *Obesity Research, 10*(3), 141-149.

Gordon-Larsen, P., McMurray, R. G., & Popkin, B. M. (2000). Determinants of adolescent physical activity and inactivity patterns. *Pediatrics, 105*(6), e83-e83.

Gortmaker, S.L., Must, A., Sobol, A.M., Peterson, K., Colditz, G.A., & Dietz, W.H. (1996). Television viewing as a cause of increasing obesity among children in the United States, 1986-1990. *Archives of Pediatric Adolescent Medicine, 150*: 356-362.

Green, L.W. (2006). Public health asks of systems science: to advance our evidence-based practice, can you help us get more practice-based evidence? *American Journal of Public Health, 96*: 406-409.

Ha, A., Bae, S., Urrutia-Rojas, X., & Singh, K.P. (2005). Eating and physical activity practices in risk of overweight and overweight children: compliance with US Department of Agriculture food guide pyramid and with National Association for Sport and Physical Activity guidelines for children. *Nutrition Research, 25*: 905-915.

Hamilton, N., & Bhatti, T. (1996). *Population health promotion: an integrated model of population health and health promotion.* Health Promotion Department Division.

Hamre, R., Kuester, S., Renaud, J., Williams-Piehota, P., Franco, E., Roussel, A. & Hersey, J. (2006). Improving nutrition, physical activity and obesity prevention: Performance report of the Nutrition and Physical Activity Program to prevent obesity and other chronic diseases: July 1 through December 31, 2005. Washington, DC: U.S. Government Printing Office. Retrieved February 12, 2015 from http://www.cdc.gov/obesity/downloads/NPAO_Performance_Report_2005.pdf

Hardy, L.L., Grunseit, A., Khambalia, A., Bell, C., Wolfenden, L., & Milat, A.J. (2012). Co-occurrence of obesogenic risk factors among adolescents. *Journal of Adolescent Health, 51*(3): 266-271.

Harrison, F. & Jones, A.P. (2012). A framework for understanding school based physical environmental influences on childhood obesity. *Health & Place, 18*: 639-648.

Health Canada, Canadian Society for Exercise Physiology: Canada's Physical Activity Guideline for Children. Ottawa: Minister of Public Works and Government Services Canada; 2002.

Hebden, L., Hector, D., Hardy, L.L., & King, L. (2013). A fizzy environment: availability and consumption of sugar-sweetened beverages among school students. *Preventive Medicine, 56*: 416-418.

Hill, A. (1965). The environment and disease: association or causation? *Proceedings of the Royal Society of Medicine, 58*(5), 295-300.

Hill, J., Wyatt, H., Reed, G., & Peters, J. (2003). Obesity and the environment: where do we go from here? *Science, 299*(5608), 853-855.

Health Canada, Canadian Society for Exercise Physiology: Canada's Physical Activity Guideline for Children. Ottawa: Minister of Public Works and Government Services Canada; 2002.

Hebden, L., Hector, D., Hardy, L.L., & King, L. (2013). A fizzy environment: availability and consumption of sugar-sweetened beverages among school students. *Preventive Medicine, 56*: 416-418.

Hunter, S., Leatherdale, S., Storey, K., & Carson, V. (2016). A quasi-experimental examination of how school-based physical activity changes impact secondary student mdoerate- to vigorous-intensity physical activity over time in the COMPASS study. *International Journal of Behavioral Nutrition and Physical Activity, 13*(86).

Iannotti, R.J. & Wang, J. (2013). Patterns of physical activity, sedentary behavior, and diet in US adolescents. *Journal of Adolescent Health, 53*(280-286).

Institute of Medicine (US). Committee on Accelerating Progress in Obesity Prevention, & Glickman, D. (2012). *Accelerating progress in obesity prevention: solving the weight of the nation*. Washington, DC:: National Academies Press.

Ismailov R., & Leatherdale S. (2010). Rural-urban differences in overweight and obesity among a large sample of adolescents. *International Journal of Pediatric Obesity 5*(4):351-360.

Jaime, P., & Lock, K. (2009). Do school based food and nutrition policies improve diet and reduce obesity? *Preventive Medicine, 48*, 45-53.

Janssen, I. (2007). Physical activity guidelines for children and youth. *Applied Physiology, Nutrition, and Metabolism, 32:* S109-S121.

Janssen, I., Boyce, W.F., Simpson, K. & Pickett, W. (2006). Influence of individual- and area-level measures of socioeconomic status on obesity, unhealthy eating, and physical inactivity in Canadian adolescents. *American Journal of Clinical Nutrition, 83*: 139-145.

Janssen, I., Katzmarzyk, P.T., Boyce, W.F., King, M.A., & Pickett, W. (2004). Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *Journal of Adolescent Health, 35*: 360-367.

Janssen, I. & LeBlanc, A.G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*(40).

Jekauc, D., Reimers, A.K., Wagner, M.O., & Woll, A. (2012). Prevalence and socio-demographic correlates of the compliance with the physical activity guidelines in children and adolescents in Germany. *BMC Public Health, 12*(714).

Jessor, R., & Jessor, S. L. (1977). Problem behavior and psychosocial development: A longitudinal study of youth.

Judd, J., Frankish, C. J., & Moulton, G. (2001). Setting standards in the evaluation of community-based health promotion programmes—a unifying approach. *Health promotion international, 16*(4), 367-380.

Kahn, J.A., Huang, B., Gillman, M.W., Field, A.E., Austin, S.B., Colditz, G.A., & Frazier, A.L. (2008). Patterns and determinants of physical activity in US adolescents. *Journal of Adolescent Health, 42*: 369-377.

Katz, D. (2009). School-based interventions for health promotion and weight control: not just waiting on the world to change. *Annual Review of Public Health, 30*, 253-272.

Katzmarzyk, P. T. (2008). Obesity and physical activity among Aboriginal Canadians. *Obesity*, *16*(1), 184-190.

Katzmarzyk, P. (2011). The economic costs associated with physical inactivity and obesity in Ontario. *THe Health & Fitness Journal of Canada, 4*(4), 31-40.

Kiefer, L., Frank, J., Di Ruggiero, E., Dobbins, M., Manuel, D., Gully, P. R., & Mowat, D. (2005). Fostering evidence-based decision-making in Canada: examining the need for a Canadian

population and public health evidence centre and research network. *Canadian Journal of Public Health/Revue Canadienne de Sante'e Publique*, I1-I19.

Kim, Y., Barreira, T., & Kang, M. (2016). Concurrent associations of physical activity and screen-based sedentary behavior on obesity among US adolescents: a latent class analysis. *J Epidemiol, 26*(3), 137-144.

Kirk, S., Penney, T., & McHugh, T. (2010). Characterizing the obesogenic environment: the state of the evidence with directions for future research. *Obesity Reviews, 11*(2), 109-117.

Koning, M., Hoekstra, T., de Jong, E., Visscher, T., Seidell, J., & Renders, C. (2016). Identifying developmental trajectories of body mass index in childhood using latent class growth (mixture) modelling: associations with dietary, sedentary and physical activity behaviors: a longitudinal study. *BMC Public Health, 16*, 1128.

Krebs, N., Himes, J., Jacobson, D., Nicklas, T., Guilday, P., & Styne, D. (2007). Assessment of child and adolescent overweight and obesity. *Pediatrics, 120*, S193-S228.

Kropski, J.A., Keckley, P.H., & Jensen, G.L. (2008). School-based obesity prevention programs: an evidence-based review. *Obesity, 16*(5): 1009-1018.

Kubik, Martha Y. Lytle, L.A., Hannan, P.J., Perry, C.L., & Story, M. (2003). The association of the school food environment with dietary behaviors of young adolescents. *American Journal of Public Health 93*(7): 1168-1173.

Kubik, M. Y., Lytle, L. A., & Story, M. (2005). Schoolwide food practices are associated with body mass index in middle school students. *Archives of Pediatrics & Adolescent Medicine, 159*(12), 1111-1114.

Langlois, K., & Garriguet, D. (2011). Sugar consumption among Canadians of all ages. *Health Reports, 22:* 23-27.

Landsberg, B., Plachta-Danielzik, S., Lange, D., Johannsen, M., Seiberl, J., & Müller, M. J. (2010). Clustering of lifestyle factors and association with overweight in adolescents of the Kiel Obesity Prevention Study. *Public Health Nutrition, 13*(10A), 1708-1715.

Lanza, H. I.; Grella, C. E.; & Chung, P. J. (2014). Does adolescent weight status predict problematic substance use patterns? *American Journal of Health Behavior, 38(5),* 708-716.

Langford, R., Campbell, R., Magnus, D., Bonell, C., Murphy, S., Waters, E., et al. (2011). The WHO Health Promoting School framework for improving the health and well-being of students and staff. *Cochrane Database Syst Rev, 1*.

Larson, N., Davey, C., Hoffman, P., Kubik, M., & Nanney, M. (2015). District wellness policise and school-level practices in Minnesota, USA. *Public Health Nutrition, 19*(1), 26-35.

Laxer, R. E., & Janssen, I. (2013). The proportion of excessive fast-food consumption attributable to the neighbourhood food environment among youth living within 1 km of their school. *Applied Physiology, Nutrition, and Metabolism, 39*(4), 480-486.

Leatherdale, S. T. (2009). Evaluating School-Based Tobacco Control Programs and Policies: An Opportunity Gained and Many Opportunities Lost. *Canadian Journal of Program Evaluation, 24*(3), 89-106.

Leatherdale, S. T., & Wong, S. (2009). Peer reviewed: association between sedentary behavior, physical activity, and obesity: inactivity among active kids. *Preventing chronic disease, 6*(1).

Leatherdale, S.T. (2015). An examination of the co-occurrence of modifiable risk factors associated with chronic disease among youth in the COMPASS study. *Cancer Causes & Control, 26*(4), 519-528.

Leatherdale, S.T., & Ahmed, R. (2011). Screen-based sedentary beahviours among a nationally representative sample of youth: are Canadian kids couch potatoes? *Chronic Disease Injuries in Canada, 31*: 141-146.

Leatherdale, S. T., Manske, S., Faulkner, G., Arbour, K., & Bredin, C. (2010). A multi-level examination of school programs, policies and resources associated with physical activity among elementary school youth in the PLAY-ON study. *International Journal of Behavioral Nutrition and Physical Activity, 7*(6).

Leatherdale, S. T., Faulkner, G., & Arbour-Nicitopoulos, K. (2010). School and Student Characteristics Associated With Screen-Time Sedentary Behavior Among Students in Grades 5-8, Ontario, Canada, 2007-2008. *Preventing Chronic Disease, 7*(6).

Leatherdale, S.T., & Laxer, R.E. (2013). Reliability and validity of the weight status and dietary intake measures in the COMPASS questionnaire: are the self-reported measures of body mass index (BMI) and Canada's Food Guide servings robust? *International Journal of Behavioral Nutrition and Physical Activity, 10*:42.

Leatherdale, S. T., & Papadakis, S. (2011). A multi-level examination of the association between older social models in the school environment and overweight and obesity among younger students. *Journal of youth and adolescence, 40*(3), 361-372.

Leatherdale, S.T., & Rynard, V. (2013) A cross-sectional examination of modifiable risk factors for chronic disease among a nationally representative sample of youth: are Canadian students graduating high school with a failing grade for health? *BMC Public Health, 13(569)*.

Leech, R. M., McNaughton, S. A., & Timperio, A. (2014b). Clustering of children's obesity-related behaviours: associations with sociodemographic indicators. *European Journal of Clinical Nutrition, 68*(5), 623-628.

Leech, R.M., McNaughton, S.A., & Timperio, A. (2014a). The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review. *International Journal of Behavioral Nutrition and Physical activity, 11*(4).

Lobstein, T. & Swinburn, B. (2007). Health promotion to prevent obesity. In : McQueen, Jones C eds. Global perspective son health promotion effectiveness. New York: Springer New York, 125-150.

Loprinzi, P.D., Cardinal, B.J., Loprinzi, K.L., & Lee, H. (2012). Benefits and environmental determinants of physical activity in children and adolescents. *Obesity Facts (5)*: 597-610.

Lowry, R., Galuska, D. A., Fulton, J. E., Wechsler, H., & Kann, L. (2002). Weight management goals and practices among US high school students: associations with physical activity, diet, and smoking. *Journal of Adolescent Health, 31*(2), 133-144.

Ludwig, D. S., Peterson, K. E., & Gortmaker, S. L. (2001). Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *The Lancet, 357*(9255), 505-508.

McAloney, K., Graham, H., Law, C., & Platt, L. (2013). A scoping review of statistical approaches to the analysis of multiple health-related behaviours. *Preventive Medicine, 56*(6), 365-371.

McLeroy, K., Bibeau, D., Steckler, A., & Clanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly, 15*(4), 351-377.

Madsen, K. A. (2011). School-based body mass index screening and parent notification: a statewide natural experiment. *Archives of pediatrics & adolescent medicine, 165*(11), 987-992.

Marti, A., Moreno-Aliaga, M.J., Hebebrand, J., & Martinez, J.A. (2004). Genes, lifestyles and obesity. *International Journal of Obesity and Related Metabolic Disorders, 28*(suppl 3): S29-S36.

Marshall, S.J., Biddle, S.J.H., Gorely, T., Cameron, N., & Murdey, I. (2004). Relationships between media use, body fatness, and physical activity in children and youth: a meta-analysis. *International Journal of Obesity, 28*: 1238-1246.

Martinez-Gomez, D., Tucker, J., Heelan, K.A., Welk, G.J., & Eisenmann, J.C., (2009). Associations between sedentary behavior and blood pressure in young children. *Archives of Pediatric Adolescent Medicine, 163*: 724-730.

Masse, L.C., de Niet-Fitzgerald, J.E., Watts, A.W., Naylor, P.J., & Saewyc, E.M. (2014). Associations between the school food environment, student consumption and body mass index of Canadian adolescents. *International Journal of Behavioral Nutrition and Physical Activity, 11*(29).

McKenna, M.L. (2010). Policy options to support healthy eating in schools. *Canadian Journal of Public Health, 101*(Suppl 2): S14-S17.

McKinnon, R.A., Orleans, C. T., Kumanyika, S. K., Haire-Joshu, D., Krebs-Smith, S. M., Finkelstein, E. A., Brownell, K.D., Thompson, J.W., & Ballard-Barbash, R. (2009). Considerations for an obesity policy research agenda. *American Journal of Preventive Medicine, 36*(4), 351-357.

McLeroy, K.R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterlly, 15*(4): 351-377.

Meija, D., Berchtold, A., Belanger, R.E., Kuntsche, E.N., Michaud, P.A., & Suris, J.C. (2012). Frequency and effects of meeting health behaviour guidelines among adolescents. *European Journal of Public Health, 23*(1): 8-13.

Menschik, D., Ahmed, S., Alexander, M.H., & Blum, R.W. (2008). Adolescent physical activities as predictors of young adult weight. *Archives of Pediatrics & Adolescent Medicine, 162*(1): 29-33.

Miech, R.A., Kumanyika, S.K., Stettler, N., Link, B.G., Phelan, J.C., & Chang, V.W. (2006). Trends in the association of poverty with overweight among U.S. adolescents, 1971-2004. *JAMA, 295*: 2385-2393.

Mitchell, J. A., Pate, R. R., Beets, M. W., & Nader, P. R. (2013). Time spent in sedentary behavior and changes in childhood BMI: a longitudinal study from ages 9 to 15 years. *International Journal of Obesity*, *37*(1), 54-60.

Morrison, W., & Kirby, P. (2010). *Schools as a setting for promoting positive mental health: Better practices and perspectives*. Joint Consortium for School Health.

Morton, K., Atkin, A., Corder, K., Suhrcke, M., & van Sluijs, E. (2015). The school environment and adolescent physical activity and sedentary behaviour: a mixed-studies systematic review. *Obesity Reviews, 17*, 142-158.

Muller, M., Asbeck, I., Mast, M., Langnase, K., & Grnd, A. (2001). Prevention of obesity - more than an intention. Concept and fresh results of the Kiel Obesity Prevention Study (KOPS). *International Journal of Obesity and Related Metabolic Disorders, 23*(Supplement 1), 66-74.

Must, A., & Strauss, R. (1999). Risks and conseqeunces of childhood and adolescent obesity. *International Journal of Obesity and Related Metabolic Disorders, 23*, S2-S11.

Must, A., & Tybor, D. (2005). Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth. *International Journal of Obesity, 29*, S84-S96.

Naylor, P. J., Macdonald, H. M., Warburton, D. E., Reed, K. E., & McKay, H. A. (2008). An active school model to promote physical activity in elementary schools: action schools! BC. *British Journal of Sports Medicine*, *42*(5), 338-343.

Niemeier, H.M., Raynor, H.A., Lloyed-Richardson, E.E., Rogers, M.L., & Wing, R.R. (2006). Fast food consumption and breakfast skipping: predictors of weight gain from adolescence to adulthood in a nationally representative sample. *Journal of Adolescent Health, 39*: 842-849.

Nelson, M.C., Gordon-Larsen, P., Adair, L.S., & Popkin, B.M. (2005). Adolescent physical activity and sedentary behavior: patterning and long-term maintenance. *American Journal of Preventive Medicine, 28*(3): 259-266.

Nelson, M.C., Neumark-Sztainer, D., Hannan, P.J., Sirard, J.R., & Story, M. (2006). Longitudinal and secular trends in physical activity and sedentary behavior during adolescence. *Pediatrics, 118*: e1627-e1634.

Nutbeam, D. (2001). Evidence-based public policy for health: matching research to policy need. *Global Health Promotion*, 15.

O'Malley, P.M., Johnston, L.D., Delva, J., Terry-McElrath, Y.M. (2009). School physical activity environment related to student obesity and activity: a national study of school and students. *Journal of Adolescent Health, 45*: S71-S81.

O'Malley, P., Johnston, L., Delva, J., Bachman, J., & Schulenberg, J. (2007). Variation in obesity among American secondary school students by school and school characteristics. *American Journal of Preventive Medicine, 33*: S187-S194.

O'toole, T. P., Anderson, S., Miller, C., & Guthrie, J. (2007). Nutrition services and foods and beverages available at school: results from the School Health Policies and Programs Study 2006. *Journal of School Health, 77*(8), 500-521.

Ogden, C., Carroll, M., Kit, B., & Flegal, K. (2008). Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA, 311*(8), 806-814.

Pasch, K. E., Nelson, M. C., Lytle, L. A., Moe, S. G., & Perry, C. L. (2008). Adoption of risk-related factors through early adolescence: associations with weight status and implications for causal mechanisms. *Journal of Adolescent Health, 43*(4), 387-393.

Pate, R.R., Freedson, P.S., Sallis, J.F., Taylor, W.C., Sirard, J., Trost, S.G., & Dowda, M. (2002). Compliance with physical activity guidelines: prevalence in a population of children and youth. *Annals of Epidemiology, 12*: 303-308.

Patrick, K., Norman, G.J., Calfas, K.J., Sallis, J.F., Zabinski, M.R., Rupp, J., & Cella, J. (2004). Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. *Archives of Pediatric and Adolescent Medicine, 158*: 385-390.

Peeters, A., Barendregt, J., Willekens, F., Mackenbach, J., Al Mamun, A., & Bonneux, L. (2003). Obesity in adulthood and its consequences for life expectancy: a life-table analysis. *Annals of Internal Medicine, 138*, 24-32.

Petticrew, M., Cummins, S., Ferrell, C., Findlay, A., Higgins, C., Hoy, C., et al. (2005). Natural experiments: an underused tool for public health? *Public Health, 119*(9), 751-757.

Pratt, C.A., Stevens, J., & Daniels, S. (2008). Childhood obesity prevention and treatment: recommendations for future research. *American Journal of Preventive Medicine, 35*(3): 249-252.

Rabin, B.A., Brownson, R.C., Haire-Joshu, D., et al. (2008). A glossary for dissemination and implementation research in health. *Journal of Public Health Management and Practice, 14*: 117-123.

Ramanathan, S., Allison, K.R., Faulkner, G., & Dwyer, J.M. (2008). Challenges in assessing the implementation and effectiveness of physical activity and nutrition policy interventions as natural experiments. *Health Promotion International, 23*(3): 290-297.

Rampersaud, G.C., Pereira, M.A., Girard, B.L., Adams, J., & Metzl, J.D. (2005). Breakfast habits, nutritional status, body weight, and academic performance in children and adolescents. *Journal of the American Dietetic Association, 105*(5): 743-760.

Reedy, J., & Krebs-Smith, S.M. (2010). Dietary sources of energy, solid fats, and added sugars among children and adolescents in the United States. *Journal of the American Dietetic Association, 110*: 1477-1484.

Rennie, K.L., Johnson, L., & Jebb, S.A. (2005). Behavioural determinants of obesity. *Best Practice and Research Clinical Endocrinology and Metabolism, 19*(3): 343-358.

Rey-Lopez, J.P., Vicente-Rodriguez, G., Biosca, M., & Moreno, L.A. (2008). Sedentary behaviour and obesity development in children and adolescents. *Nutrition, Metabolism & Cardiovascular Diseases, 18*: 242-251.

Roberts, K., Shields, M., de Groh, M., Aziz, A., & Gilberta, J. (2012). Overweight and obesity in children and adolescents: results from the 2009 to 2011 Canadian Health Measures Survey. *Health Rep, 23*(3), 37-41.

Robinson, T. N., Hammer, L. D., Wilson, D. M., Killen, J. D., Kraemer, H. C., Hayward, C., & Taylor, C. B. (1993). Does television viewing increase obesity and reduce physical activity? Cross-sectional and longitudinal analyses among adolescent girls. *Pediatrics, 91*(2), 273-280.

Roseman, M. G., Riddell, M. C., & Haynes, J. N. (2011). A content analysis of kindergarten-12th grade school-based nutrition interventions: taking advantage of past learning. *Journal of nutrition education and behavior, 43*(1), 2-18.

Rosenkranz, R.R., & Dzewaltowski, D.A. (2008). Model of the home food environment pertaining to childhood obesity. *Nutrition Reviews, 66*(3):123-140.

Rossiter, M.D., Evers, S.E., & Pender, A.C. (2012). Adolescents' diets do not comply with 2007 Canada's food guide recommendations. *Appetite, 59*, 668-672.

Rovner, A. J., Nansel, T. R., Wang, J., & Iannotti, R. J. (2011). Food sold in school vending machines is associated with overall student dietary intake. *Journal of Adolescent Health, 48*(1), 13-19.

Rychetnik, L., Frommer, M., Hawe, P., & Shiell, A. (2002). Criteria for evaluation evidence on public health interventions. *Journal of Epidemiology and Community Health, 56*, 119-127.

Sacks, G., Swinburn, B., & Lawrence, M. (2009). Obesity policy action framework and analysis grids for a comprehensive policy approach to reducing obesity. *Obesity Reviews, 10*(1), 76-86.

Safron, M., Cislak, A., Gaspar, T., & Luszczynska, A. (2011). Effects of school-based interventions targeting obesity-related behaviors and body weight change: a systematic umbrella review. *Behavioral Medicine, 37*(1), 15-25.

Sallis, J.F., Conway, T.L., Prochaska, J.J., McKenzie, T.L., Marshall, S.J., & Brown, M. (2001). The association of school environments with youth physical activity. *American Journal of Public Health, 91*, 618-620.

Sallis, J.F., McKenzie, T.L., Conway, T.L., Elder, J.P., et al. (2003). Environmental interventions for eating and physical activity. A randomized controlled trial in middle schools. *American Journal of Preventive Medicine, 24*(3), 209-217.

Sallis, J. F., Owen, N., & Fisher, E. B. (2008). Ecological models of health behavior. *Health behavior and health education: Theory, research, and practice,4*, 465-486.

Sallis, J.F., Prochaska, J., & Taylor, W. (2000). A review of correlates of physical activity of children and adolescents. *Medicine and Science in Sports and Exercise, 32*, 963.975.

Sanchez, A., Norman, G.J., Sallis, J.F., Calfas, K.J., Cella, J. & Patrick, K. (2007). Patterns and correlates of physical activity and nutrition behaviors in adolescents. *American Journal of Preventive Medicine 32*(2): 124-130.

Schwartz, A., Leardo, M., Aneja, S., & Elbel, B. (2016). Effect of a school-based water intervention on child body mass index and obesity. *JAMA Pediatrics, 170*(3), 220-226.

Services, U. D. (2010). *Disease and Conditions Index: what are overweight and obesity?* Bethesda, MD.

Shields, M., & Tremblay, M. (2010). Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. *Int J Pediatr Obes, 5*(3), 265-273.

Singh A.S., Chinapaw M.J., Brug, J., & van Mechelen, W. (2007). Short-term effects of school-based weight gain prevention among adolescents. *Archives of Pediatric and Adolescent Medicine, 161,* 565-571.

Singh, A., Mulder, C., Twisk, J., Van Mechelen, W., & Chinapaw, M. (2008). Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obesity Reviews, 9*(5), 474-488.

Sjoberg RL, Nilsson KW, & Leppert J. (2005) Obesity, shame, and depression in school-aged children: a population-based study. *Pediatrics 116*(3), e389-92.

Speller, V. (2001). The next challenge-getting evidence into practice. *Global Health Promotion*, 20.

Stamatakis, K. A., Leatherdale, S. T., Marx, C., Yan, Y., Colditz, G. A., & Brownson, R. C. (2012). Where Is Obesity Prevention on the Map? Distribution and Predictors of Local Health Department Prevention Activities in Relation to County-Level Obesity Prevalence in the US. *Journal of public health management and practice: JPHMP, 18*(5), 402.

Stokols, D., Allen, J., Bellingham, R.L. (1996). The social ecology of health promotion: implications for research and practice. *American Journal of Health Promotion, 10,* 247-251.

Storey, K.E., Hanning, R.M., Lambraki, I.A., Driezen, P., Fraser, S.N., & McCargar, L.J. (2009). Determinants of diet quality among Canadian adolescents. *Revue Canadienne de la pratique et de la recherché en dietetique, 70*(2), 58-65.

Story, M. (1999). School-based approaches for preventing and treating obesity. *International Journal of Obesity, 23,* S43-S51.

Story, M., Nanney, M., & Schwartz, M. (2009). Schools and obesity prevention: creating school environments and policies to promote healthy eating and physical activity. *The Milbank Quarterly, 87*(1), 71-100.

Story, M., Neumark-Sztainer, D., & French, S. (2002). Individual and environmental influences on adolescent eating behaviors. *Journal of the American Dietetic Association, 102*(3), S40-S51.

Story, M., Sallis, J.F., & Orleans, C.T. (2009)b. Adolescent obesity: towards evidence-based policy and environmental solutions. *Journal of Adolescent Health, 45,* S1-S5.

Strong, W.B., Malina, R.M., Blimkie, C.J. Daniels, S.R., Dishman, R.K., Gutin, B.G., Hergenroeder, A.C., Must, A., Nixon, P.A., Pivarnik, J.M., Rowland, T., Trost, S., & Trudeau, F. (2005). Evidence-based physical activity for school-age youth. *The Journal of Pediatrics, 146,* 732-737.

Sweeting, HN. (2007). Measurement and definitions of obesity in childhood and adolescence: a field guide for the uninitiated. *Nutrition Journal, 6*(32).

Swinburn, B., Egger, G., & Raza, F. (1999). Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Preventive Medicine, 29*(6), 563-570.

Taber, D. R., Chriqui, J. F., Perna, F. M., Powell, L. M., & Chaloupka, F. J. (2012). Weight status among adolescents in states that govern competitive food nutrition content. *Pediatrics, 130*(3), 437-444.

Taylor, J.P., Evers, S., & McKenna, M. (2005). Determinants of healthy eating in children and youth. *Canadian Journal of Public Health, 96*(supplement 3), S20-S26

Te, M.L., Mallard, S., & Mann, J. (2013). Dietary sugars and body weight: systematic review and meta-analysis of randomised controlled trials and cohort studies. *BMJ, 346*, e7492.

Timlin, M.T., Pereira, M.A., Story, M., & Neumark-Sztainer, D. (2008). Breakfast eating and weight change in a 5-year prospective analysis of adolescents: Project EAT (Eating Among Teens). *Pediatrics, 121*: e638-e645.

Tob, C., Chew, S., & Tan, C. (2002). Prevention and control of non-communicable diseases in Singapore: a review of national health promotion programmes. *Singapore Medical Journal, 43*, 333-340.

Tremblay, M., LeBlanc, A., Kho, M., Saunders, T., Larouche, R., Colley, R., et al. (2011). Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *International Journal of Behavioural Nutrition and Physical Activity, 8*(98).

Tremblay, M. S., LeBlanc, A. G., Janssen, I., Kho, M. E., Hicks, A., Murumets, K., ... & Duggan, M. (2011)a. Canadian sedentary behaviour guidelines for children and youth. *Applied Physiology, Nutrition, and Metabolism, 36*(1), 59-64.

Tremblay, M. S., Warburton, D. E., Janssen, I., Paterson, D. H., Latimer, A. E., Rhodes, R. E., Kho, M.E., Hicks, A., LeBlanc, A.G., Zehr, L., Murumets, K., & Duggan, M. (2011)c. New Canadian physical activity guidelines. *Applied Physiology, Nutrition, and Metabolism, 36*(1), 36-46.

Trudeau, F., & Shephard, R.J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition & Physical Activity, 5*(10).

Turrell, G., Oldenburg, B., Mcguffog, I., & Dent, R. (1999). *Socioeconomic determinants of health: towards a national research program and a policy adn intervention agenda.* Queensland: Queensland University of Technology.

Ullrich-French, S.C., Power, T.G., Daratha, K.B., Bindler, R.C., & Steele, M.M. (2010). Examination of adolescents' screen time and physical fitness as independent correlates of weight status and blood pressure. *Journal of Sports Sciences, 28*(11), 1189-1196.

US Department of Health and Human Services. Disease and Conditions Index: what are overweight and obesity? *Bethesda, MD* (2010).

van der Horst, K., Chinapaw, M.J., Twisk, J.W.R., & van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Medicine & Science in Sports & Exercise,* 39(8), 1241-1250.

van der Horst, K., Timperio, A., Crawford, D., Roberts, R., Brug, J., & Oenema, A. (2008). The school food environment: associations with adolescent soft drink and snack consumption. *American Journal of Preventive Medicine, 35,* 217-223.

van der Sluis, M.E., Lien, N., Twisk, J.W.R., Steenhuis, I.H.M., Bere, E., Klepp, K.I., & Wind, M. (2010). Longitudinal associations of energy balance-related behaviours and cross-sectional associations of clusters and body mass index in Norwegian adolescents. *Public Health Nutrition, 13*(10A): 1716-1721.

Veugelers, P.J. & Fitzgerald, A.L. (2005). Effectiveness of school programs in preventing childhood obesity: a multilevel comparison. *American Journal of Public Health, 95*(3): 432-435.

Veugelers, P., & Schwartz, M. (2010). Comprehensive school health in Canada. *Canadian Journal of Public Health*, S5-S8.

Wabitsch, M. (2000). Overweight and obesity in European children: definition and diagnostic procedures, risk factors, and consequences for later health outcome. *European Journal of Pediatrcis, 159,* S8-S13.

Wang, D., & Steward, D. (2013). The implementation and effectiveness of school-based nutrition promotion programmes using a health-promoting schools approach: a systematic review. *Public Health Nutrition, 16*(6), 1082-1100.

Wang, X., Ouyang, Y., Liu, J., Zhu, M., Zhao, G., Bao, W., & Hu, F. B. (2014). Fruit and vegetable consumption and mortality from all causes, cardiovascular disease, and cancer: systematic review and dose-response meta-analysis of prospective cohort studies. *Bmj*, *349*, g4490.

Wechsler, H., Devereaux, R.S., Davis, M., & Collins, J. (2000). Using the school environment to promote physical activity and healthy eating. *Preventive Medicine, 31,* S121-S137.

Willms, J.D., Tremblay, M.S., & Katzmarzyk, P.T. (2003). Geographic and demographic variation in the prevalence of overweight Canadian children. *Obesity Reviews, 11*(5), 668-673.

Winson, A. (2008). School food environments and the obesity issue: content, structural determinants, and agency in Canadian high schools. *Agriculture and Human Values, 25*(4), 499.

Withrow, D., & Alter, D. (2011). The economic burden of obesity worldwide: a systematic review of the direct costs of obesity. *Obesity Reviews, 12*(2), 131-141.

World Health Organization. "Ottawa charter for health promotion." (1986).

World Health Organization. (2008). School policy framework: implementation of the WHO global strategy on diet, physical activity and health.

Chapter 3 (COMPASS Methods)

Bredin, C., & Leatherdale, S.T. (2014). Development of the COMPASS student questionnaire. *COMPASS Technical Report Series, 2(2)*. Waterloo, Ontario: University of Waterloo. Available at: www.compass.uwaterloo.ca.

Brener, N., Mcmanus, T., Galuska, D., Lowry, R., & Wechsler, H. (2003). Reliability and validity of self-reported height and weight among high school students. *Journal of Adolescent Health, 32*: 281.287.

Church, D., & Leatherdale, S.T. (2013). Development of the COMPASS School Health Profile. *COMPASS Technical Report Series, 1*(1). Waterloo, Ontario: University of Waterloo. Available at: www.compass.uwaterloo.ca}.

Cole, T.J., Bellizzi, M.C., Flegal, K.M., & Dietz, W.H. (2000). Establishing a standard definition for childhood overweight and obesity worldwide: international survey. *British Medical Journal, 320*(7244): 1240-1243.

Currie, C., Samdal, O., Boyce, W., & Smith, B. (2001). Health behaviour in school-aged children: a World Health Organization cross-national study. *Research protocol for the 2001/2 survey.* Edinburgh, Scotland: Child and Adolescent Health Research Unit, University of Edinburgh, 2001.

Elton-Marshall, T., Leatherdale, S.T., Manske, S.R., Wong, K., Ahmed, R., & Burkhalter, R. (2011). Research methods of the Youth Smoking Survey (YSS). *Chronic Diseases and Injuries in Canada, 32*: 47-54.

Hunsberger, S., Murray, D., Davis, C., & Fabsitz, R. R. (2001). Imputation strategies for missing data in a school-based multi-centre study: the Pathways study. *Statistics in medicine*, *20*(2), 305-316.

Leatherdale, S.T., Manske, S., Wong, S., & Cameron, R. (2009). Integrating research, policy and practice in school-based physical activity prevention programming: The School Health Action, Planning, and Evaluation System (SHAPES) physical activity module. *Health Promotion Practice, 10*: 254-261.

Leatherdale, S.T., Pouliou, T., Church, D., & Hobin, E. (2011). The association between overweight and opportunity structures in the built environment: a multi-level analysis among elementary school youth in the PLAY-ON study. *International Journal of Public Health, 56*: 237-246.

Leatherdale, S.T., & Ahmed, R. (2011). Screen-based sedentary beahviours among a nationally representative sample of youth: are Canadian kids couch potatoes? *Chronic Disease Injuries in Canada, 31*: 141-146.

Leatherdale, S.T., & Laxer, R.E. (2013). Reliability and validity of the weight status and dietary intake measures in the COMPASS questionnaire: are the self-reported measures of body mass index (BMI) and Canada's Food Guide servings robust? *International Journal of Behavioral Nutrition and Physical Activity, 10*:42.

Leatherdale, S.T., & Rynard, V. (2013) A cross-sectional examination of modifiable risk factors for chronic disease among a nationally representative sample of youth: are Canadian students graduating high school with a failing grade for health? *BMC Public Health, 13(569)*.

Leatherdale, S.T., Laxer, R.E., & Faulkner, G. (2014). Reliability and validity of the physical activity and sedentary behaviour measures in the COMPASS study. *COMPASS Technical Report Series, 2*(1). Waterloo, Ontario: University of Waterloo. Available at: www.compass.uwaterloo.ca.

Leatherdale, S.T. (2015). An examination of the co-occurrence of modifiable risk factors associated with chronic disease among youth in the COMPASS study. *Cancer Causes & Control, 26*(4), 519-528.

Leatherdale, S. T., Brown, K. S., Carson, V., Childs, R. A., Dubin, J. A., Elliott, S. J., Faulkner, G., Hammond, D., Manske, S., Sabiston, C.M., Laxer, R.E., Bredin, C., & Thompson-Haile, A. (2014). The COMPASS study: a longitudinal hierarchical research platform for evaluating natural experiments related to changes in school-level programs, policies and built environment resources. *BMC public health, 14*(1), 331.

Roberts, C., Freeman, J., Samdal, O., Schnohr, C. W., De Looze, M. E., Nic Gabhainn, S., ... & Rasmussen, M. (2009). The Health Behaviour in School-aged Children (HBSC) study: methodological developments and current tensions. *International journal of public health, 54*, 140-150.

Thompson-Haile, A., Bredin, C., & Leatherdale, S.T. (2013). Rationale for using active-information passive-consent permission protocol in COMPASS. *COMPASS Technical Report Series, 1*(6). Waterloo, Ontario: University of Waterloo. Available at: www.compass.uwaterloo.ca.

Thompson-Haile, A., Laxer, R.E., Ledgley, C. & Leatherdale, S.T. Knowledge Broker Procedures for Contacting and Working with Participating Schools: COMPASS Technical Report Series. 2015; 3(3). Waterloo, Ontario: University of Waterloo. Available at www.compass.uwaterloo.ca.

Wong, S.L., Leatherdale, S.T., & Manske, S. (2006). Reliability and validity of a school-based physical activity questionnaire. *Medicine and Science in Sports and Exercise, 38*, 1593-1600.

Chapter 4: Manuscript 1

(1) Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet 2014;384:9945:766-781.
(2) Ogden CL, Carroll MD, Fryar CD, Flegal KM. Prevalence of obesity among adults and youth: United States, 2011–2014. NCHS data brief, 2015;219:1-8.
(3) Wabitsch M, Moss A, Kromeyer-Hauschild, K. (2014). Unexpected plateauing of childhood obesity rates in developed countries. BMC medicine. 2014:12:1.

(4) Roberts KC, Shields M, de Groh M, Aziz A, Gilbert JA. Overweight and obesity in children and adolescents: results from the 2009 to 2011 Canadian Health Measures Survey. Health rep. 2012:23:3:37-41.
(5) Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. International Journal of Obesity, 2011:35:7:891-898.
(6) Telama R. Tracking of physical activity from childhood to adulthood: a review. Obes Facts. 2009, 2: 187-195
(7) Biddle SJ, Pearson N, Ross GM, Braithwaite R: Tracking of sedentary behaviours of young people: a systematic review. Prev Med. 2010, 51:345-351
(8) Eaton DK, Kann L, Kinchen S, Shanklin S, Ross J, Hawkins J, et al. Youth risk behavior surveillance-United States, 2009. Morbidity and Mortality Weekly Report,2011:59.
(9) Leatherdale ST, Rynard V. A cross-sectional examination of modifiable risk factors for chronic disease among a nationally representative sample of youth: are Canadian students graduating high school with a failing grade for health? BMC Public Health,2013:13:1.
(10) Sanchez A, Norman GJ, Sallis JF, Calfas KJ, Cella J, Patrick K. Patterns and correlates of physical activity and nutrition behaviors in adolescents. American journal of preventive medicine, 2007:32:2:124-130.
(11) Carson V, Faulkner G, Sabiston CM, Tremblay MS, Leatherdale ST. Patterns of movement behaviors and their association with overweight and obesity in youth. International journal of public health,2015:60:5: 551-559.
(12) BeLu, R, Francis LA, Rollins B, Colaco B. One size does not fit all: identifying risk profiles for overweight in adolescent population subsets. Journal of Adolescent Health, 2009:45:5:517-524.
(13) Leatherdale ST. An examination of the co-occurrence of modifiable risk factors associated with chronic disease among youth in the COMPASS study. Cancer Causes & Control,2015:26:4:519-528.
(14) Terzian MA, Andrews KM, Moore KA. Preventing multiple risky behaviors among adolescents: seven strategies. Research to Results Brief, 2011: 24
(15) Kumanyika SK, Obarzanek E, Stettler N, Bell R, Field AE, et al. Population-based prevention of obesity the need for comprehensive promotion of healthful eating, physical activity, and energy balance: A scientific statement from American heart association council on epidemiology and prevention, interdisciplinary committee for prevention (formerly the expert panel on population and prevention science). Circulation, 2008:118:4: 428-464.
(16) Ogilvie KK, Eggleton A. Obesity in Canada: A Whole-of-Society Approach for a Healthier Canada. The Standing Senate Committee on Social Affairs, Science and Technology. 2016.
(17) Huh J, Riggs NR, Spruijt-Metz D, Chou CP, Huang Z, Pentz M. Identifying patterns of eating and physical activity in children: a latent class analysis of obesity risk. *Obesity*, 2011:19:3: 652-658.
(18) Leatherdale ST. An examination of the co-occurrence of modifiable risk factors associated with chronic disease among youth in the COMPASS study. Cancer Causes & Control,2015:26:4:519-528.
(19) Herciu AC, Laxer RE, Cole A, Leatherdale ST. A Cross-sectional Study Examining Factors Associated with Youth Binge Drinking in the COMPASS Study: Year 1 Data. Journal of Alcoholism & Drug Dependence. 2014.
(20) Dierker LC, Vesel F, Sledjeski EM, Costello D, Perrine N. Testing the dual pathway hypothesis to substance use in adolescence and young adulthood. Drug and Alcohol Dependence. 2007; 87:1: 83-93.

(21) Rose JS, Chassin L, Presson C, Sherman SJ, Stein MD, Col N. A latent class typology of young women smokers. Addiction. 2007;102:8:1310-1319.
(22) Duncan AE, Bucholz KK, Neuman RJ, Agrawal A, Madden PA, Heath AC. Clustering of eating disorder symptoms in a general population female twin sample: a latent class analysis. Psychological Medicine. 2007;37:8:1097-1107.
(23) Laska MN, Pasch KE, Lust K, Story M, Ehlinger E. Latent class analysis of lifestyle characteristics and health risk behaviors among college youth. Prevention Science. 2009;10:4:376-386.
(24) Heitzler C, Lytle L, Erickson D, Sirard J, Barr-Anderson D, Story M. Physical activity and sedentary activity patterns among children and adolescents: a latent class analysis approach. Journal of Physical Activity and Health. 2011;8:4:457.
(25) Leech RM, McNaughton SA, Timperio A. The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review. International Journal of Behavioral Nutrition and Physical Activity. 2014;11:1.
(26) Leatherdale, ST, Brown KS, Carson V, Childs RA, Dubin JA, et al. The COMPASS study: a longitudinal hierarchical research platform for evaluating natural experiments related to changes in school-level programs, policies and built environment resources. BMC Public Health. 2014;14:1.
(27) Thompson-Haile A, Bredin C, Leatherdale, ST. Rationale for using an active-information passive-consent permission protocol. COMPASS Technical Report Series, 2013; vol 1. Waterloo, Ontario: University of Waterloo.
(28) Tremblay MS, Warburton DE, Janssen I, Paterson DH, Latimer AE, Rhodes RE, et al. New Canadian physical activity guidelines. Applied Physiology, Nutrition, and Metabolism, 2011;36:1: 36-46.
(29) Leatherdale ST, Laxer RE, Faulkner G. Reliability and validity of the physical activity and sedentary behaviour measures in the COMPASS study. COMPASS Technical Report Series, 2014; vol 2. Waterloo, Ontario: University of Waterloo.
(30) Health Canada: Eating Well with Canada's Food Guide. 2011, Minister of Health, http://www.hc-sc.gc.ca/fn-an/alt_formats/hpfb-dgpsa/pdf/food-guide-aliment/print_eatwell_bienmang-eng.pdf [Accessed June, 2016]
(31) Leatherdale ST, Laxer RE. Reliability and validity of the weight status and dietary intake measures in the COMPASS questionnaire: are the self-reported measures of body mass index (BMI) and Canada's food guide servings robust? International Journal of Behavioral Nutrition and Physical Activity. 2013;10:1.
(32) Tremblay MS, LeBlanc AG, Janssen I, Kho ME, Hicks A, Murumets K et al. Canadian sedentary behaviour guidelines for children and youth. Applied Physiology, Nutrition, and Metabolism. 2011;36:1: 59-64.
(33) Centers for Disease Control and Prevention. 5 A Day Works! Atlanta: U.S. Department of Health and Human Services; 2005, http://www.cdc.gov/nccdphp/dnpa/nutrition/health_professionals/programs/5aday_works.pdf [Accessed June, 2016]
(34) Growth reference 5–19 years, 2007. http://www.who.int/growthref/who2007_bmi_for_age/en/index.html. Accessed 02 December 2016.
(35) Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999-2000. JAMA, 2002;288:14: 1728-1732.

(36) Lanza ST, Collins LM, Lemmon DR, Schafer JL. PROC LCA: A SAS procedure for latent class analysis. Structural Equation Modeling. 2007;14:4: 671-694.
(37) Akaike H. A new look at the statistical model identification. IEEE Transactions on Automatic Control. 1974;19:6: 716-723.(38) Schwarz G. Estimating the dimension of a model. The Annals of Statistics. 1978;6:2: 461-464.
(39) Sugiura N. Further analysts of the data by akaike's information criterion and the finite corrections: Further analysts of the data by akaike's. Communications in Statistics-Theory and Methods. 1978;7:1: 13-26.
(40) Muthén B, Muthén LK. Integrating person-centered and variable-centered analyses: Growth mixture modeling with latent trajectory classes. Alcoholism: Clinical and Experimental Research, 2000:24:6:882-891.(41) De La Haye K, D'Amico EJ, Miles JN, Ewing B, Tucker JS. Covariance among multiple health risk behaviors in adolescents. PloS One. 2014;9:5: e98141.
(42) Hardy LL, Grunseit A, Khambalia A, Bell C, Wolfenden L, Milat AJ. Co-occurrence of obesogenic risk factors among adolescents. Journal of Adolescent Health. 2012;51:3:265-271.
(43) Jessor R, Jessor SL. Problem behavior and psychosocial development: A longitudinal study of youth. 1977.
(44) Pate RR, Heath GW, Dowda M, Trost SG. Associations between physical activity and other health behaviors in a representative sample of US adolescents. American Journal of Public Health. 1996;86*:*11: 1577-1581.
(45) Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Medicine and Science in Sports and Exercise. 2000;32:5: 963-975.
(46) MacArthur GJ, Smith MC, Melotti R, Heron J, Macleod J, Hickman M, et al. Patterns of alcohol use and multiple risk behaviour by gender during early and late adolescence: the ALSPAC cohort. Journal of Public Health. 2012;34 Suppl 1: i20-i30.
(47) Alberga AS, Sigal RJ, Goldfield G, Prud'Homme D, Kenny GP. Overweight and obese teenagers: why is adolescence a critical period? Pediatric Obesity. 2012;7:4: 261-273.
(48) Nelson MC, Gordon-Larsen P, Adair LS, Popkin BM. Adolescent physical activity and sedentary behavior: patterning and long-term maintenance. American Journal of Preventive Medicine. 2005;28:3:259-266.
(49) Eccles JS, Barber BL. Student council, volunteering, basketball, or marching band what kind of extracurricular involvement matters? Journal of Adolescent Research, 1999:14:1: 10-43.
(50) Miller KE, Hoffman JH, Barnes GM, Farrell MP, Sabo D, Melnick, MJ. Jocks, gender, race, and adolescent problem drinking. Journal of Drug Education. 2003;33*:*4: 445-462.
(51) Dodd LJ, Al-Nakeeb Y, Nevill A, Forshaw MJ. Lifestyle risk factors of students: a cluster analytical approach. Preventive Medicine. 2010;51:1:73-77.
(52) Schuit AJ, van Loon AJM, Tijhuis M, Ocké MC. Clustering of lifestyle risk factors in a general adult population. Preventive Medicine. 2002;35:3:219-224.
(53) Rossiter MD, Evers SE, Pender AC. Adolescents' diets do not comply with 2007 Canada's food guide recommendations. Appetite. 2012;59:3: 668-672.
(54) Storey KE, Hanning RM, Lambraki IA, Driezen P, Fraser SN, McCargar LJ. Determinants of diet quality among Canadian adolescents. Canadian Journal of Dietetic Practice and Research. 2009;70:2: 58-65.

(55) French SA, Story M, Neumark-Sztainer D, Fulkerson JA, Hannan P. Fast food restaurant use among adolescents: associations with nutrient intake, food choices and behavioral and psychosocial variables. International Journal of Obesity & Related Metabolic Disorders. 2001;25:12.
(56) Rampersaud GC, Pereira MA, Girard BL, Adams J, Metzl JD. Breakfast habits, nutritional status, body weight, and academic performance in children and adolescents. Journal of the American Dietetic Association. 2005;105:5:743-760.
(57) Slater MD. Theory and method in health audience segmentation. Journal of Health Communication. 1996;1:3:267-284.
(58). Boone-Heinonen J, Gordon-Larsen P, Adair LS. Obesogenic clusters: multidimensional adolescent obesity-related behaviors in the US. Ann Behav Med. 2008;36:3:217-230.
(59) Elgar FJ, Roberts C, Tudor-Smith C, Moore L. Validity of self-reported height and weight and predictors of bias in adolescents. Journal of Adolescent Health. 2005;37:5: 371-375.
(60) Fung C, Kuhle S, Lu C, Purcell M, Schwartz M, Storey K, Veugelers PJ. From" best practice" to" next practice": the effectiveness of school-based health promotion in improving healthy eating and physical activity and preventing childhood obesity. International Journal of Behavioral Nutrition and Physical Activity. 2012;9:1.
(61) Noar SM, Benac CN, Harris MS. Does tailoring matter? Meta-analytic review of tailored print health behavior change interventions. Psychological Bulletin. 2007;133:4: 673.
(62) Ohri-Vachaspati P, DeLia D, DeWeese RS, Crespo NC, Todd M, Yedidia MJ. The relative contribution of layers of the Social Ecological Model to childhood obesity. Public Health Nutrition. 2015:18:11:2055-2066.
(63) Lautenschlager L, Smith C. Understanding gardening and dietary habits among youth garden program participants using the Theory of Planned Behavior. Appetite. 2007:49:1:122-30.

Manuscript 2

1. Roberts K, Shields M, de Groh M, Aziz A, Gilbert J. Overweight and obesity in children and adolescents: results from the 2009 to 2011 Canadian Health Measures Survey. Health Rep. 2012;23(3):37.
2. Reilly JJ, Methven E, McDowell ZC, Hacking B, Alexander D, Stewart L et al. Health consequences of obesity. Arch Dis Child. 2003 Sep 1; 88(9):748-52.
3. Gortmaker S, Must A, Perrin J, Sobol A, Dietz W. Social and economic consequences of overweight in adolescence and young adulthood. New England Journal of Medicine. 1993;329(14):1008-1012.
4. Dietz WH, Gortmaker SL. Preventing obesity in children and adolescents.
Annu Rev Public Health. 2001 May;22(1):337-53.
5. Battista K, Leatherdale ST. Estimating how extra calories from alcohol consumption are likely an overlooked contributor to youth obesity. Health Promot Chronic Dis Prev Can. 2017 Jun;37(6):194.
6. Pasch KE, Velazquez CE, Cance JD, Moe SG, Lytle LA. Youth substance use and body composition: does risk in one area predict risk in the other? Journal of Youth and Adolescence. 2012 Jan 1;41(1):14-26.
7. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc. 2000 May 1;32(5):963-75.
8. Nelson MC, Neumark-Stzainer D, Hannan PJ, Sirard JR, Story M. Longitudinal and secular trends in physical activity and sedentary behavior during adolescence. Pediatrics. 2006 Dec 1;118(6):e1627-34.

9. Leech RM, McNaughton SA, Timperio A. The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review. Int J Behav Nutr Phys Act. 2014 Jan 22;11(1):4.
10. Laxer RE, Brownson RC, Dubin JA, Cooke M, Chaurasia A, Leatherdale ST. Clustering of risk-related modifiable behaviours and their association with overweight and obesity among a large sample of youth in the COMPASS study. BMC public health. 2017 Jan 21;17(1):102.
11. Carson V, Faulkner G, Sabiston CM, Tremblay MS, Leatherdale ST. Patterns of movement behaviors and their association with overweight and obesity in youth. Int J Public Health. 2015 Jul 1;60(5):551-9.
12. Leatherdale ST. An examination of the co-occurrence of modifiable risk factors associated with chronic disease among youth in the COMPASS study. Cancer Causes Control. 2015 Apr 1;26(4):519-28.
13. Nonnemaker JM, Morgan-Lopez AA, Pais JM, Finkelstein EA. Youth BMI trajectories: evidence from the NLSY97. Obesity. 2009 Jun 1;17(6):1274-80.
14. Moore LL, Gao D, Bradlee ML, Cupples LA, Sundarajan-Ramamurti A, Proctor MH, et al. Does early physical activity predict body fat change throughout childhood? Preventive medicine. 2003 Jul 31;37(1):10-7.
15. Berkey CS, Rockett HR, Field AE, Gillman MW, Frazier AL, Camargo CA, Colditz GA. Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. Pediatrics. 2000 Apr 1;105(4):e56-.
16. Elgar FJ, Roberts C, Moore L, Tudor-Smith C. Sedentary behaviour, physical activity and weight problems in adolescents in Wales. Public health. 2005 Jun 30;119(6):518-24.
17. Kemper HC, Post GB, Twisk JW, Van Mechelen W. Lifestyle and obesity in adolescence and young adulthood: results from the Amsterdam Growth and Health Longitudinal Study (AGAHLS). Int J Obes. 1999 Apr 2;23.
18. Must A, Tybor DJ. Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth. Int J Obes. 2005 Sep 1;29:S84-96.
19. Burke V, Beilin LJ, Simmer K, Oddy WH, Blake KV, Doherty D, et al. Predictors of body mass index and associations with cardiovascular risk factors in Australian children: a prospective cohort study. Int J Obes. 2005 Jan 1;29(1):15-23.
20. Haerens L, Vereecken C, Maes L, De Bourdeaudhuij I. Relationship of physical activity and dietary habits with body mass index in the transition from childhood to adolescence: a 4-year longitudinal study. Public Health Nutrition. 2010 Oct;13(10A):1722-8.
21. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 2011 Apr 23;6(1):42.
22. Leatherdale ST, Brown KS, Carson V, Childs RA, Dubin JA, Elliott SJ, et al. The COMPASS study: a longitudinal hierarchical research platform for evaluating natural experiments related to changes in school-level programs, policies and built environment resources. BMC Public Health. 2014 Apr 8;14(1):331.
23. Qian W, Battista K, Bredin C, Stephen Brown K, Leatherdale ST. Assessing longitudinal data linkage results in the COMPASS study. COMPASS Technical Report Series. Waterloo: University of Waterloo; 2015.
24. Baraldi AN, Enders CK. An introduction to modern missing data analyses. Journal of school psychology. 2010 Feb 28;48(1):5-37.

25. Leatherdale ST, Laxer RE. Reliability and validity of the weight status and dietary intake measures in the COMPASS questionnaire: are the self-reported measures of body mass index (BMI) and Canada's food guide servings robust? Int J Behav Nutr Phys Act. 2013 Apr 5;10(1):42.
26. Ruel E, Reither EN, Robert SA, Lantz PM. Neighborhood effects on BMI trends: Examining BMI trajectories for Black and White women. Health & Place. 2010 Mar 31;16(2):191-8.
27. Lanza ST, Collins LM, Lemmon DR, Schafer JL. PROC LCA: A SAS procedure for latent class analysis. Structural Equation Modeling. 2007 Oct 23;14(4):671-94.
28. Delva J, Johnston LD, O'Malley PM. The epidemiology of overweight and related lifestyle behaviors: racial/ethnic and socioeconomic status differences among American youth. Am J Prev Med. 2007 Oct 31;33(4):S178-86.
29. Laird NM, Ware JH. Random-effects models for longitudinal data. Biometrics. 1982 Dec 1:963-74.
30. Singh AS, Mulder C, Twisk JW, Van Mechelen W, Chinapaw MJ. Tracking of childhood overweight into adulthood: a systematic review of the literature. Obesity Rev. 2008 Sep 1;9(5):474-88.
31. Berkey CS, Rockett HR, Gillman MW, Field AE, Colditz GA. Longitudinal study of skipping breakfast and weight change in adolescents. Int J Obes. 2003 Oct 1;27(10):1258-66.
32. Mitchell JA, Pate RR, Beets MW, Nader PR. Time spent in sedentary behavior and changes in childhood BMI: a longitudinal study from ages 9 to 15 years. Int J Obes. 2013 Jan 1;37(1):54-60.
33. Gordon-Larsen P, Adair LS, Popkin BM. Ethnic differences in physical activity and inactivity patterns and overweight status. Obesity. 2002 Mar 1;10(3):141-9.
34. Boone JE, Gordon-Larsen P, Adair LS, Popkin BM. Screen time and physical activity during adolescence: longitudinal effects on obesity in young adulthood. Int J Behav Nutr Phys Act. 2007 Jun 8;4(1):26.
35. Chinapaw MJ, Proper KI, Brug J, Van Mechelen W, Singh AS. Relationship between young peoples' sedentary behaviour and biomedical health indicators: a systematic review of prospective studies. Obesity Rev. 2011 Jul 1;12(7).
36. Leatherdale ST. Factors associated with communication-based sedentary behaviors among youth: are talking on the phone, texting, and instant messaging new sedentary behaviors to be concerned about? J Adolesc Health. 2010 Sep 30;47(3):315-8.
37. Fulton JE, Dai S, Steffen LM, Grunbaum JA, Shah SM, Labarthe DR. Physical activity, energy intake, sedentary behavior, and adiposity in youth. Am J Prev Med. 2009 Jul 31;37(1):S40-9.
38. Patrick K, Norman GJ, Calfas KJ, Sallis JF, Zabinski MF, Rupp J, et al. Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. JAMA Pediatr. 2004 Apr 1;158(4):385-90.
39. White HR, McMorris BJ, Catalano RF, Fleming CB, Haggerty KP, Abbott RD. Increases in alcohol and marijuana use during the transition out of high school into emerging adulthood: The effects of leaving home, going to college, and high school protective factors. J Stud Alcohol Drugs. 2006 Nov;67(6):810-22.
40. Henry KL. Who's skipping school: Characteristics of truants in 8th and 10th grade. J Sch Health. 2007 Jan 1;77(1):29-35.
41. de Winter AF, Visser L, Verhulst FC, Vollebergh WA, Reijneveld SA. Longitudinal patterns and predictors of multiple health risk behaviors among adolescents: the TRAILS study. Prev Med. 2016 Mar 31;84:76-82.

42. Jáuregui A, Villalpando S, Rangel-Baltazar E, Lara-Zamudio YA, Castillo-García MM. Physical activity and fat mass gain in Mexican school-age children: a cohort study. BMC pediatrics. 2012 Jul 28;12(1):109.
43. Brault MC, Aimé A, Bégin C, Valois P, Craig W. Heterogeneity of sex-stratified BMI trajectories in children from 8 to 14years old. Physiol Behav. 2015 Apr 1;142:111-20.
44. Patte KA, Laxer R, Qian W, Leatherdale ST. Weight Perception and Weight-control Intention among Youth in the COMPASS Study. Am J Health Behav. 2016 Sep 1;40(5):614-23.
45. van der Sluis ME, Lien N, Twisk JW, Steenhuis IH, Bere E, Klepp KI, Wind M. Longitudinal associations of energy balance-related behaviours and cross-sectional associations of clusters and body mass index in Norwegian adolescents. Public Health Nutr. 2010 Oct;13(10A):1716-21.
46. Leatherdale S, Rynard V. A cross-sectional examination of modifiable risk factors for chronic disease among a nationally representative sample of youth: are Canadian students graduating high school with a failing grade for health? BMC Public Health, 2012;13(1), 569.
47. Nelson MC, Kocos R, Lytle LA, Perry CL. Understanding the perceived determinants of weight-related behaviors in late adolescence: a qualitative analysis among college youth. J Nutr Educ Behav. 2009 Aug 31;41(4):287-92.
48. Cairney J, Leatherdale ST, Faulkner GE. A longitudinal examination of the interrelationship of multiple health behaviors. Am J Prev Med. 2014 Sep 30;47(3):283-9.
49. Press, T. C. (2017, January 31). The Toronto Star. Retrieved March 10, 2017, from thestar.com: https://www.thestar.com/news/canada/2017/01/31/canada-pressing-forward-with-marijuana-legalization-amid-us-uncertainty.html}
50. Roux AD. A glossary for multilevel analysis. J Epidemiol Community Health. 2002 Aug 1;56(8):588-94.
51. Kuskowska-Wolk A, Karlsson P, Stolt M, Rössner S. The predictive validity of body mass index based on self-reported weight and height. Int J Obes. 1989;13(4):441-53.
52. Flegal KM, Tabak CJ, Ogden CL. Overweight in children: definitions and interpretation. Health Educ Res. 2006 Oct 27;21(6):755-60.

Manuscript 3

Baranowski, T., Anderson, C., & Carmack, C. (1998). Mediating variable framework in physical activity interventions: How are we doing? how might we do better? *American Journal of Preventive Medicine, 15*(4), 266-297.

Baranowski, T., Mendlein, J., Resincow, K., Frank, E., Weber Cullen, K., & Baranowski, J. (2000). Physical activity and nutrition in children and youth: An overview of obesity prevention. *Preventive Medicine, 31*, S1-S10.

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

Brownson, R., Chriqui, J., Burgeson, C., Fisher, M., & Ness, R. (2010). Translating epidemiology into policy to prevent childhood obesity: the case for promoting physical activity in school settings. *Ann Epidemiol, 20*(6), 436-444.

Budd. (2006). School-based obesity prevention: research, challenges, and recommendations.

Butler-Jones, D. (2008). *The Chief Public Health Officer's Report on the state of public health in Canada 2008: addressing health inequalities.* Ottawa, ON: Public Health Agency of Canada.

Coleman, K., Tiller, C., Sanchez, J., Heath, E., Sy, O., Milliken, G., & Dzewaltowski, D. (2005). Prevention of the epidemic increase in child risk of overweight in low-income schools: the El Paso coordinated approach to child health. *Archives of Pediatrics & Adolescent Medicine, 159*(3), 217-224.

Cook-Cottone, C., Casey, C., Feeley, T., & Baran, J. (2009). A meta-analytic review of obesity prevention in schools: 1997-2008. *Psychology in the Schools, 46*(8), 695-719.

Cullen, K., & Watson, K. (2009). The impact of the Texas public school nutrition policy on student food selection and sales in Texas. *Am J Public Health, 99*, 706-712.

Cummins, S., Petticrew, M., Higgins, C., Findlay, A., & Sparks, L. (2005). Large scale food retailing as an intervention for diet and health: quasi-experimental evaluation of a natural experiment. *Journal of Epidemiology and Community Health, 59*, 1035-1040.

Deschesnes, M., Martin, C., & Jomphe-Hill, A. (2003). Comprehensive approaches to school health promotion: how to achieve broader implementation? . *Health Promotion International, 18*(4), 387-396.

Ewing, R., Brownson, R., & Berrigan, D. (2006). Relationship between urban sprawl and weight of United States youth. *Am J Prev Med, 31*(6), 464-474.

Fung, C., Kuhle, S., Lu, C., Purcell, M., Schwartz, M., Storey, K., & Veugelers, P. (2012). From "best practice" to "next practice": the effectiveness of school-based health promotion in improving healthy eating and physical activity and preventing childhood obesity. *International Journal of Behavioral Nutrition and Physical Activity, 9*(27). doi:10.1186/1479-5868-9-27

Fung, C., McIsaac, J., Kuhle, S., Kirk, S., & Veugelers, P. (2013). The impact of a population-level school food and nutrition policy on dietary intake and body weights of Canadian children. *Preventive Medicine, 57*(6), 934-940.

Gonzalez-Suarez, C., Worley, A., Grimmer-Somers, K., & Dones, V. (2009). School-based interventions on childhood obesity: A meta-analysis. *Am J Prev Med, 37*(5), 418-427.

Harris, K., Kuramoto, L., Schulzer, M., & Retallack, J. (2009). Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. *CMAJ, 180*(7), 19-26.

Kafatos, A., Manios, Y., & Moschandreas, J. (2005). Health and nutrition education in primary schools of Crete: follow-up changes in body mass index and overweight status. *Eur J Clin Nutr, 50*(9), 1090-1092.

Katz, D., O'connell, M., Nijke, V., Yeh, M., & Nawaz, H. (2008). Strategies for the prevention and control of obesity in the school setting: systematic review and meta-analysis. *International Journal of Obesity, 32*(12), 1780-1789.

Kropski, J., Keckley, P., & Jensen, G. (2008). School-based obesity prevention programs: an evidence-based review. *Obesity, 16*(5), 1009-1018.

Kubik, M., Lytle, L., & Story, M. (2005). Schoolwide food practices are associated with body mass index in middle school students. *Archives of Pediatric Adolescent Medicine, 159*(12), 1111-1114.

Laird, N., & Ware, J. (1982). Random-effects models for longitudinal data. *Biometrics*, 963-974.

Laxer, RE., Brownson, R., Dubin, J., Cooke, M., Chaurasia, A., & Leatherdale, S. (2017). Clustering of risk-related modifiable behaviours and their association with overweight and obesity among a large sample of youth in the COMPASS study. *BMC Public Health, 17*(1), 102.

Leatherdale, S. (2015). An examination of the co-occurrence of modifiable risk factors associated with chronic disease among youth in the COMPASS study. *Cancer Causes & Control, 26*(4), 519-528.

Leatherdale, S., & Laxer, R. (2013). Reliability and validity of the weight status and dietary intake measures in the COMPASS questionnaire: are the self-reported measures of body mass index (BMI) and Canada's Food Guide servings robust? *International Journal of Behavioral Nutrition and Physical Activity, 10*(1).

Leatherdale, S., Brown, K., Carson, V., Childs, R., Dubin, J., Elliott, S., . . . Thompson-Haile, A. (2014). The COMPASS Study: a longitudinal hierarchical research platform for evaluating natural experiments related to changes in school-level programs, policies, and built environment resources. *BMC Public Health, 14*(331).

Lee, S. M. (2011). School health guidelines to promote healthy eating and physical activity. *Centers for Disease Control and Prevention: Morbidity and Mortality Weekly Report, 60*(5).

Luepker, R., Perry, C., McKinlay, S., Nader, P., Parcel, G., Stone, E., . . . Kelder, S. (1996). Outcomes of a field trial to improve children's dietary patterns and physical activity: the Child and Adolescent Trial for Cardiovascular Health (CATCH). *JAMA, 275*(10), 768-776.

Madsen, K. (2011). School-based body mass index screening and parent notification. *Arch Pediatr Adolesc Med, 165*(11), 987-992.

Mendoza, J., Watson, K., & Cullen, K. (2010). Change in dietary energy density after implementation of the Texas Public School Nutrition Policy. *J Am Diet Assoc, 110*, 434-440.

Michie, S., van Stralen, M., & Robert, W. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation Science, 6*(1), 2-11.

O'Malley, P., Johnston, L., Delva, J., Bachman, J., & Schulenberg, J. (2007). Variation in obesity among American secondary school students by school and school characteristics. *American Journal of Preventive Medicine, 33*(4S).

Petticrew, M., Cummins, S., Ferrell, C., Findlay, A., Higgins, C., Hoy, C., . . . Sparks, L. (2005). Natural experiments: an underused tool for public health? *Public Health, 119*, 751-757.

Pyle, S., Sharkey, J., Yetter, G., Felix, E., & Furlong, M. (2006). Fighting an epidemic: the role of schools in reducing childhood obesity. *Psychology in the Schools, 43*(3), 361-376.

Qian, W., Battista, K., Bredin, C., Brown, K., & Leatherdale, S. (2015). Assessing longitudinal data linkage results in the COMPASS Study. *Technical Report Series, 3*(4).

Ramanathan, S., Allison, K., Faulkner, G., & Dwyer, J. (2008). Challenges in assessing the implementation and effectiveness of physical activity and nutrition policy interventions as natural experiments. *Health Promotion International, 23*(3), 290-297.

Reilly, J., & Kelly, J. (2011). Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. *International Journal of Obesity, 35*(7), 891-898.

Roberts, K., Shields, M., de Groh, M., Aziz, A., & Gilberta, J. (2012). Overweight and obesity in children and adolescents: results from the 2009 to 2011 Canadian Health Measures Survey. *Health Rep, 23*(3), 37-41.

Rose, G. (1992). *The strategy of preventive medicine.* Oxford: University Press.

Ruel, E., Reither, E., Robert, S., & Lantz, P. (2010). Neighborhood effects on BMI trends: examining BMI trajectories for Black and White women. *Health & Place, 16*(2), 191-198.

Ryan, K., Card-Higginson, P., McCarthy, S., Justus, M., & Thompson, J. (2006). Arkansas fights fat: translating research into policy to combat childhood and adolescent obesity. *Health Affairs, 25*(4), 992-1004.

Rychetnik, L., Frommer, M., Hawe, P., & Shiell, A. (2002). Criteria for evaluating evidence on public health interventions. *Journal of Epidemiology and Community Health, 56*, 119-127.

Schwartz, M., Karunamuni, N., & Veugelers, P. (2010). Tailoring and implementing comprehensive school health: the Alberta Project Promoting active Living and healthy Eating in Schools. *Revue phénEPS/PHEnex Journal, 2*(1).

Stokes, H., & Mukherjee, D. (2000). The nature of health service/school links in Australia. *Journal of School Health, 70*, 255-256.

Thompson-Haile, A., Laxer, R., Ledgley, C., & Leatherdale, S. (2015). *Knowledge broker procedures for contacting and working with participating schools.* Waterloo, Ontario: Univesrity of Waterloo.

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

Veugelers, P., & Schwartz, M. (2010). Comprehensive school health in Canada. *Canadian Journal of Public Health, 101*(Supplement 2), S5-S8.

Wang, D., & Steward, D. (2013). The implementation and effectiveness of school-based nutrition promotion programmes using a health-promoting schools approach: a systematic review. *Public Health Nutrition, 16*(6), 1082-1100.

General Discussion

Baranowski, T., Anderson, C., & Carmack, C. (1998). Mediating variable framework in physical activity interventions: how are we doing? How might we do better? *American Journal of Preventive Medicine, 15*(4), 266-298.

Battista, K., & Leatherdale, S. (2017). Estimating how extra calories from alcohol consumption are likely an overlooked contributor to youth obesity. *Health Promotion and Chronic Disease Prevention in Canada, 37*(6), 194-200.

Bauman, A., Sallis, J., Dzewaltowski, D., & Owen, N. (2002). Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *American Journal of Preventive Medicine, 23*(2), 5-14.

Black, A., & Cole, T. (2001). Biased over- or under-reporting is characteristic of individuals whether over time or by different assessment methods. *Journal of the American Dietetic Association, 101*(1), 70-80.

Borys, J., Le Bodo, Y., Jebb, S., Seidell, J., Summerbell, C., Richard, D., . . . Raffin, S. (2012). EPODE approach for childhood obesity prevention: methods, progress and international development. *Obesity Reviews*(13), 299-315.

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

Brownson, R., Fielding, J., & Maylahn, C. (2009). Evidence-based public health: a fundamental concept for public health practice. *Annual Review of Public Health, 30*, 175-201.

Brownson, R., Haire-Joshu, D., & Luke, D. (2006). Shaping the context of health: a review of environmental and policy approaches in the prevention of chronic disease. *Annual review of public health, 27*, 341-370.

Budd, G., & Volpe, S. (2006). School-based obesity prevention: research, challenges, and recommendations. *Journal of School Health, 76*(10), 485-495.

Bulter, M., & Allen, P. (2009). Understanding policy implementation processes as self-organizing systems. *Public Management Review, 10*(3), 421-440.

CDC. (2013). *Make a difference at your school.*

Christakis, N. A., & Fowler, J. H. (2007). The spread of obesity in a large social network over 32 years.

N *Engl J Med, 2007*(357), 370-379.

Collins, L., & Lanza, S. (2013). *Latent class and latent transition analysis: with applications in the social, behavioral, and health sciences (Vol 718).* John Wiley & Sons.

Cook-Cottone, C., Casey, C., Feeley, T., & Baran, J. (2009). A meta-analytic review of obesity prevention in schools: 1997-2008. *Psychology in the Schools, 46*(8), 659-719.

Craig, P., Cooper, C., Gunnell, D., Haw, S., Lawson, K., Macintyre, S., . . . Thompson, S. (2012). Using natural experiments to evaluate population health interventions: new MRC guidelines. *J Epidemiol Community Health, 66*(12), 1182-1186.

Craig, P., Katikireddi, S., Leyland, A., & Popham, F. (2017). Natural experiments: an overview of methods, approaches, and contributions to public health intervention research. *Annual Review of Public Health, 38*, 39-56.

Dobbins, M., De Corby, K., Robeson, P., Husson, H., & Tirilis, D. (2009). School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6-18. *Cochrane database syst rev, 1*(1).

Domitrovich, C., Bradshaw, C., Poduska, J., Hoagwood, K., Buckley, J., Olin, S., . . . Ialongo, N. (2008). Maximizing the implementation quality of evidence-based preventive interevntions in schools: a conceptual framework. *Advances in School Mental Health Promotion, 1*(3), 6-28.

Dunning, T. (2008). Improving causal inference: Strengths and limitations of natural experiments. *Political Research Quarterly, 61*(2), 282-293.

Durlak, J., & Dupre, E. (2008). Implementation matters: a review of research on the influence of implementation on program outcomes and the factors affecting implementation. *American Journal of Community Psychology, 41*(3-4), 327-350.

Dwyer, J., Allison, K., Barrera, M., Hansen, B., Goldenberg, E., & Boutilier, M. (2003). Teachers' perspective on barriers to implementing physical activity curriculum guidelines for school children in Toronto. *Canadian Journal of Public Health*, 448-452.

Estabrooks, P., Lee, R., & Gyurcsik, N. (2003). Resources for physical activity participation: does availability and accessibility differ by neighborhood socioeconomic status? *Annals of behavioral medicine, 25*(2), 100-104.

Farhat, T., Iannotti, R., & Simons-Morton, B. (2010). Overweight, obesity, youth, and health-risk behaviors. *American Journal of Preventive Medicine, 38*(3), 258-267.

Field, A., Camargo, C., Taylor, C., Berkey, C., Roberts, S., & Colditz, G. (2001). Peer, parent, and media influences on the development of weight concerns and frequent dieting among preadolescent and adolescent girls and boys. *Pediatrics, 107*(1), 54-60.

Flegal, K., Tabak, C., & Ogden, C. (2006). Overweight in children: definitions and interpretation. *Health Education Research, 21*(6), 755-760.

Ford, I., & Norrie, J. (2016). Pragmatic Trials. *New England Journal of Medicine, 375*(5), 454-463.

Foster, G., Sherman, S., Borradaile, K., Grundy, K., Vander Veur, S., Nachmani, J., . . . Shults, J. (2008). A policy-based school intervention to prevent overweight and obesity. *Pediatrics, 121*(4).

French, S., Story, M., & Jeffery, R. (2001). Environmental influences on eating and physical activity. *Annual Review of Public Health, 22*(1), 309-335.

Fung, C., Kuhle, S., Lu, C., Purcell, M., Schwartz, M., Storey, K., & Veugelers, P. (2012). From "best practice" to "next practice": the effectiveness of school-based health promotion in improving healthy eating and physical activity and preventing childhood obesity. *International Journal of Behavioral Nutrition and Physical Activity, 9*(27). doi:10.1186/1479-5868-9-27

Glasgow, R., Vogt, T., & Boles, S. (1999). Evaluating the public health impact of health promotion interventions: the RE-AIM framework. *American Journal of Public Health, 89*(9), 1322-1327.

Gonzalez-Suarez, C., Worley, A., Grimmer-Somers, K., & Dones, V. (2009). School-based interventions on childhood obesity: A meta-analysis. *Am J Prev Med, 37*(5), 418-427.

Gray, W., Janicke, D., Ingerski, L., & Silverstein, J. (2008). The impact of peer victimization, parent distress, and child depression on barrier formationa dn physical activity in overweight youth. *Journal of Developmental & Behavioral Pediatrics, 29*(1), 26-33.

Hunter, S., Leatherdale, S., Storey, K., & Carson, V. (2016). A quasi-experimental examination of how school-based physical activity changes impact secondary student mdoerate- to vigorous-intensity physical activity over time in the COMPASS study. *International Journal of Behavioral Nutrition and Physical Activity, 13*(86).

Jaime, P., & Lock, K. (2009). Do school based food and nutrition policies improve diet and reduce obesity? *Preventive Medicine, 48*, 45-53.

Katz, D. (2009). School-based interventions for health promotion and weight control: not just waiting on the world to change. *Annual Review of Public Health, 30*, 253-272.

Kehm, R., Davey, C., & Nanney, M. (2015). The role of family and community involvement in the development and implementation of school nutrition and physical activity policy. *Journal of School Health, 85*, 90-99.

Khambalia, A., Dickinson, S., Hardy, L., Gill, T., & Baur, L. (2012). A synthesis of existing systematic reviews and meta-analyses of school-based behavioural interventions for controlling and preventing obesity. *Obesity Reviews, 13*, 214-233.

Kremers, S., De Bruijn, G., Visscher, T., Van Mechelen, W., De Vries, N., & Brug, J. (2006). Environmental influences on energy balance-related behaviors: a dual process view. *International Journal of Behavioral Nutrition and Physical Activity, 3*(1), 9.

Kubik, M., Lytle, L., Farbakhsh, K., Moe, S., & Samuelson, A. (2009). Food use in middle and high school fundraising: does policy support healthy practice? Results from a survey of Mineesota school principals. *J Am Diet Assoc, 109*(7), 1215-1219.

Kubik, M., Story, M., & Davey, C. (2007). Obesity prevention in schools: current role and future practice of school nurses. *Preventive Medicine, 44*(6), 504-507.

Larson, N., Davey, C., Hoffman, P., Kubik, M., & Nanney, M. (2015). District wellness policise and school-level practices in Minnesota, USA. *Public Health Nutrition, 19*(1), 26-35.

Leatherdale, S., & Laxer, R. (2013). Reliability and validity of the weight status and dietary intake measures in the COMPASS questionnaire: are the self-reported measures of body mass index (BMI) and Canada's food guide servings robust? *International Journal of Behavioral Nutrition and Physical Activity, 42*.

Leatherdale, S.T., Laxer, R.E., & Faulkner, G. (2014). Reliability and validity of the physical activity and sedentary behaviour measures in the COMPASS study. *COMPASS Technical Report Series, 2*(1). Waterloo, Ontario: University of Waterloo. Available at: HYPERLINK "http://www.compass.uwaterloo.ca" www.compass.uwaterloo.ca .

Leatherdale, S., Brown, K., Carson, V., Childs, R., Dubin, J., Elliott, S., . . . Thompson-Haile, A. (2014). The COMPASS study: a longitudinal hierarchical research platform for evaluating natural experiments related to changes in school-level programs, policies and built environment resources. *BMC Public Health, 14*(1), 331.

Leatherdale, S., Wong, S., Manske, S., & Colditz, G. (2008). Susceptibility to smoking and its association with physical activity, BMI, and weight concerns among youth. *Nicotine & Tobacco Research, 10*(3), 499-505.

Lissau, I. (2007). Prevention of overweight in the school arena. *Acta Paediatr Suppl, 96*, 12-18.

Lobstein, T., Baur, L., & Uauy, R. (2004). Obesity in children and young people: a crisis in public health. *Obesity Reviews, 5*(s1), 4-85.

Lucarelli, J., Alaimo, K., Mang, E., Martin, C., Miles, R., Bailey, D., . . . Liu, H. (2014). Facilitators to promoting health in schools: is school health climate the key? *Journal of School Health, 84*(2), 133-140.

Mayne, S., Auchincloss, A., & Michael, Y. (2015). Impact of policy and built environment changes on obesity-related outcomes: a systematic review of naturally occurring experiments. *Obesity Reviews, 16*, 362-375.

Michie, S., van Stralen, M., & West, R. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation Science, 6*(1), 42.

Morton, K., Atkin, A., Corder, K., Suhrcke, M., & van Sluijs, E. (2015). The school environment and adolescent physical activity and sedentary behaviour: a mixed-studies systematic review. *Obesity Reviews, 17*, 142-158.

Nichol, M., Pickett, W., & Janssen, I. (2009). Associations between school recreation environments and physical activity. *Journal of School Health, 79*(6), 247-254.

O'loughlin, J., Gray-Donald, K., Paradis, G., & Meshefedjian, G. (2000). One- and two-year predictors of excess weight gain among elementary school children in multiethnic, low income, inner-city neighborhoods. *American Journal of Epidemiology, 152*(8), 739-746.

O'Malley, P., Johnston, L., Delva, J., Bachman, J., & Schulenberg, J. (2007). Variation in obesity among American secondary school students by school and school characteristics. *American Journal of Preventive Medicine, 33*(4), S187-S194.

Patrick, K., Norman, G., Calfas, K., Sallis, J., Zabinski, M., Rupp, J., & Cella, J. (2004). Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. *Archives of pediatrics & adolescent medicine, 158*(4), 385-390.

Penedo, F., & Dahn, J. (2005). Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Current Opinion in Psychiatry, 18*(2), 189-193.

Petticrew, M., Cummins, S., Ferrell, C., Findlay, A., Higgins, C., Hoy, C., . . . Sparks, L. (2005). Natural experiments: an underused tool for public health? *Public Health, 119*(9), 751-757.

Piercy, K., Dorn, J., Fulton, J., Janz, K., Lee, S., McKinnon, R., . . . Lavizzo-Mourey, R. (2015). Opportunities for public health to increase physical activity among youths. *Am J Public Health, 105*, 421-426.

Pratt, C., Stevens, J., & Daniels, S. (2008). Childhood obesity prevention and treatment: recommendations for future research. *American Journal of Preventive Medicine, 35*(3), 249-252.

Ramanathan, S., Allison, K., Faulkner, G., & Dwyer, J. (2008). Challenges in assessing the implemenation and effectiveness of physical activity and nutrition policy interventions. *Health Promotion International, 23*(3), 290-297.

Ribeiro, I., Parra, D., Hoehner, C., Soares, J., Torres, A., Pratt, M., . . . Simoes, E. (2010). School-based physical education programs: evidence-based physical activity interventions for youth in Latin America. *Global Health Promotion, 17*(2), 5-15.

Roseman, M. (n.d.). A content analysis of kindergarten to 12th grade school-based nutrition interventions: taking advantage of past learning.

Ruel, E., Reitner, E., Robert, S., & Lantz, P. (2010). Neighborhood effects on BMI trends: examining BMI trajectories for Black and White women. *Health & Place, 16*(2), 191-198.

Sacks, G., Swinburn, B., & Lawrence, M. (2009). Obesity policy action framework and analysis grids for a comprehensive policy approach to reducing obesity. *Obesity Reviews, 10*(1), 76-86.

Sallis, J., Bauman, A., & Pratt, M. (1998). Environmental and policy interventions to promote physical activity. *American Journal of Preventive Medicine, 15*(4), 379-397.

Scott, M., Evenson, K., Cohen, D., & Cox, C. (2007). Comparing perceived and objectively measured access to recreational facilities as predictors of physical activity in adolescent girls. *Journal of Urban Health, 84*(3), 346.

Sharma, M. (2006). School-based interventions for childhood and adolescent obesity. *Obesity Reviews, 7*(3), 261-269.

Shoveller, J., Viehbeck, S., Di Ruggiero, E., Greyson, D., Thomson, K., & Knight, R. (2016). A critical examination of representations of context within research on population health interventions. *Critical Public Health, 26*(5), 487-500.

Snijders, T. (2005). *Power and sample size in multilevel linear models.*

Stamatakis, K., Leatherdale, S., Marx, C., Yan, Y., Colditz, G., & Brownson, R. (2012). Where is obesity prevention on the map? Distribution and predictors of local health department prevention activities in relation to county-level obesity prevalence in the US. *Journal of Public Health Managemetn and Practice: JPHMP, 18*(5), 402.

Story, M., Evans, M., Fabsitz, R., Clay, T., Holy Rock, B., & Broussard, B. (1999). The epidemic of obesity in American Indian communities and the need for childhood obesity-prevention programs1,2,3. *American Journal of Clinical Nutrition, 69*(4), 747S-754S.

Story, M., Nanney, M., & Schwartz, M. (2009). Schools and obesity prevention: creating school environments and policies to promote healthy eating and physical activity. *The Milbank Quarterly, 87*(1), 71-100.

Swinburn, B., Egger, G., & Raza, F. (1999). Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Preventive Medicine, 29*(6), 563-570.

Veugelers, P., & Schwartz, M. (2010). Comprehensive school health in Canada. *Canadian Journal of Public Health*, S5-S8.

Visscher, T., & Seidell, J. (2001). The public health impact of obesity. *Annual Review of Public Health, 22*(1), 355-375.

Waters, E., de Silva-Sanigorski, A., Burford, B., Brown, T., Campbell, K., Gao, Y., . . . Summerbell, C. (2011). Interventions for preventing obesity in children. *The Cochrane Library*.

Winson, A. (2008). School food environments and the obesity issue: content, structural determinants, and agency in Canadian schools. *Agric Hum Values, 25*, 499-511.

Zenzen, W., & Kridli, S. (2009). Integrative review of school-based childhood obesity prevention programs. *Journal of Pediatric Health Care, 23*(4), 242-258.

Appendix A:
Guidelines and Recommendations

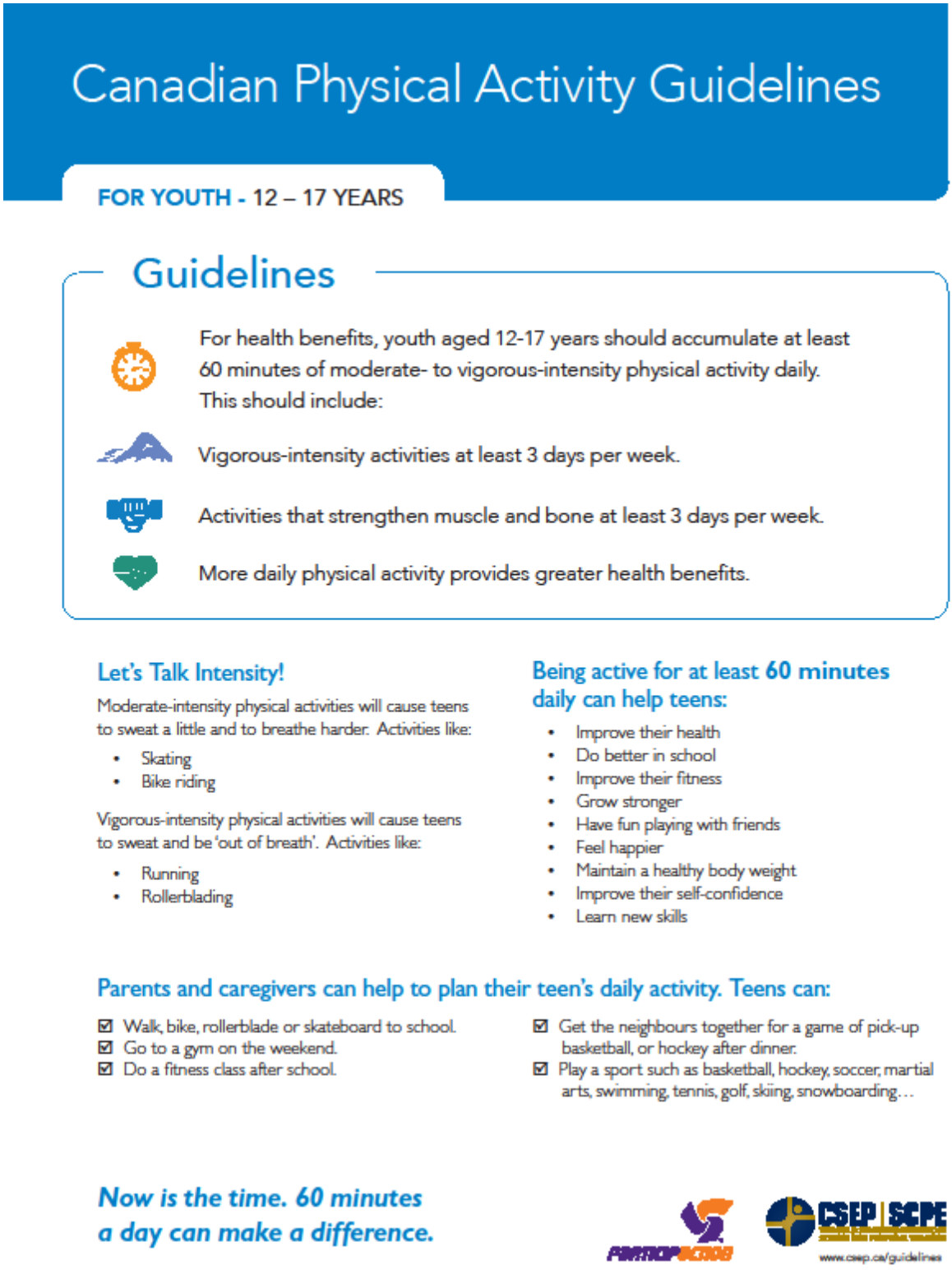

Figure 10. Canadian Physical Activity Guidelines for youth

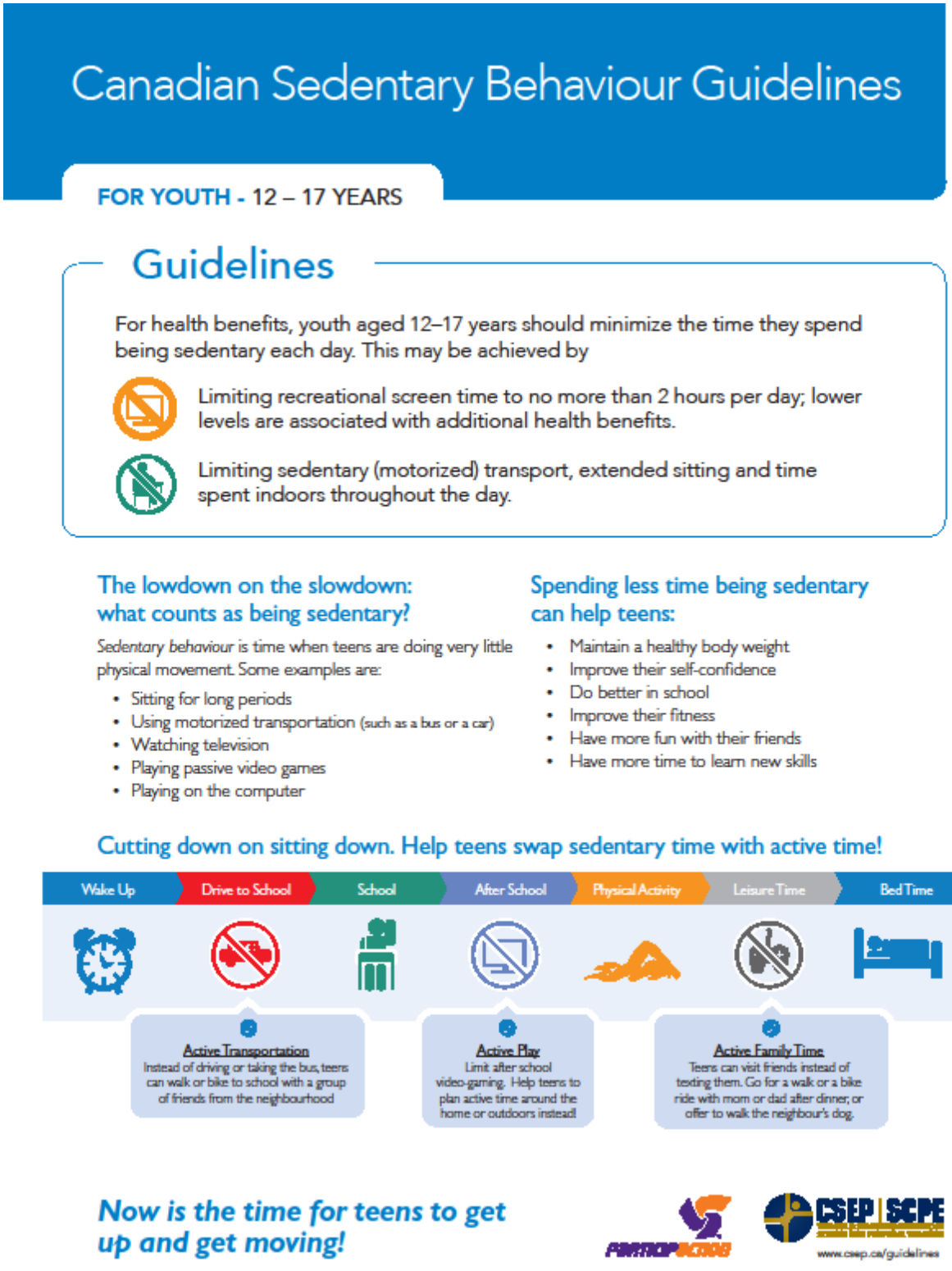

Figure 11. Canadian Sedentary Behaviour Guidelines for Youth

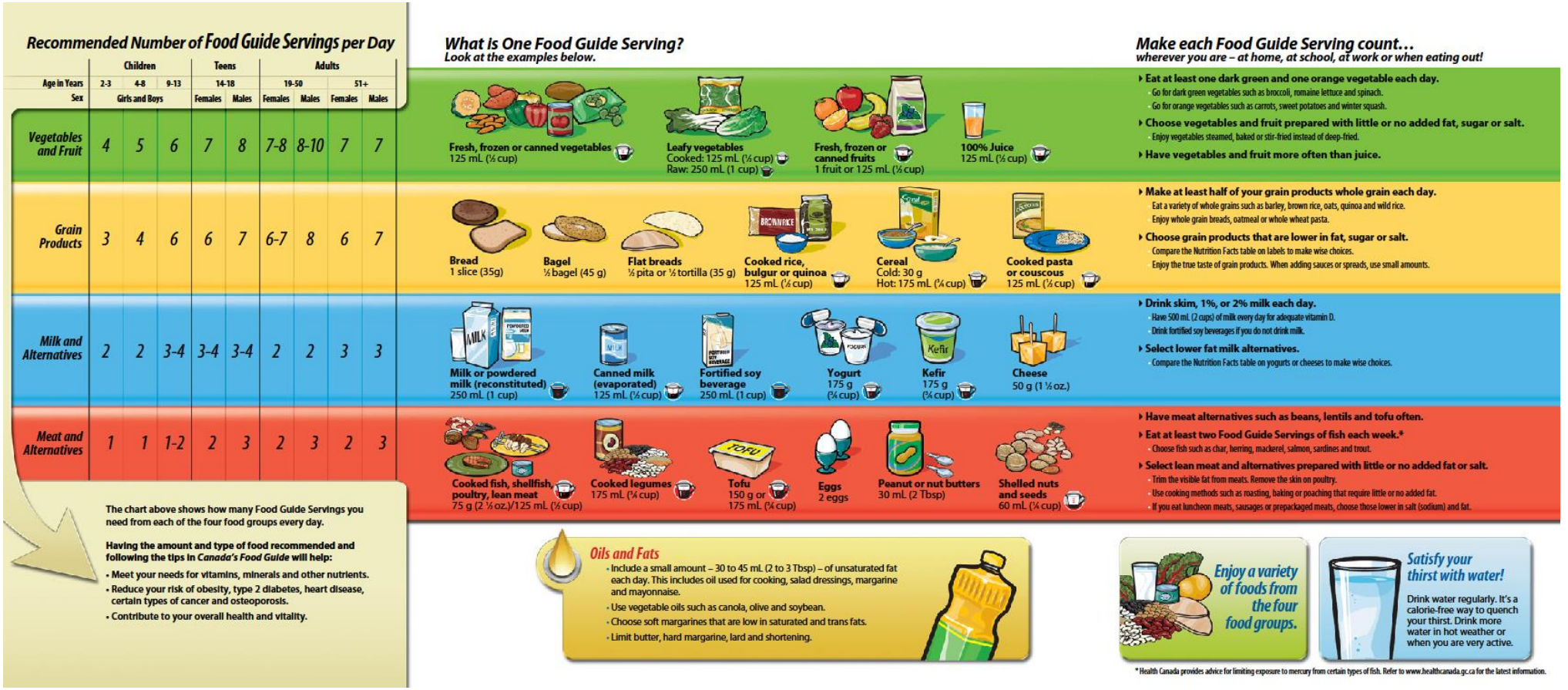

Figure 12. Canada's Food Guide

Appendix B:

Summary Tables

Table 10. Summary of studies investigating behavioural clusters in children and youth

Study	Behaviours measured	Age/geographic location	Methods	Results	Association with overweight/obesity
Alamian, 2009	- Physical inactivity - sedentary behaviour - tobacco smoking - alcohol drinking - high body mass index	10-17 years Canada	Ratio of observed over expected (O/E) proportions was used to assess the clustering of behavioural risk factors	Nearly 2/3 of youth have multiple behavioural risk factors. - Most common: ever smoking and ever drinking. - also prevalent: physical inactivity, sedentary behaviour, and high BMI	Did not assess
Beets, 2010	- physical activity - Sedentary activities - Competing activities (work, homework, household duties)	Mean age 14.9 Oregon	Latent profile analysis	5 class structure: 1. workers: moderate physical activity/high competing activities/low sedentary activities 2. non-movers: low PA/low sed 3. Movers: high PA/high sport/low sed 4. watchers: mod PA/high sed 5. reference mod PA/low sed	Classes 1, 2, and 4 members were positively associated with being overweight; class 4 more likely to be at risk for overweight.
Boone-Heinonen, 2008	36 variables – 11 diet variables, 25 activity variables, and other health behaviours	11-21 years United States	Cluster analysis to examine obesity-related behaviour patterning and identify high-risk adolescent groups Descriptive and multivariate regression analyses	7 clusters identified for males, 6 for females Males: - School clubs and sports - sports - moderately active - sedentary behaviours - junk food and smoke - dieters -low diet and activity	Compared to school clubs and sports clusters, prevalent and incident obesity were higher for most clusters (in females, not males)

			to compare sociodemographic and prevalence and incidence of obesity across the clusters	Females: - school clubs and sports - average diet and activity - high consumer - sedentary behaviours - junk food and low activity - restrictive dieting and smoking	
Cameron, 2011	- Physical activity - sedentary behaviour - eating behaviours (meeting FV recommendations, energy dense foods)	Mother report of 5-12 year old child Victoria, Australia	Proportion meeting guidelines Cluster analysis	5 cluster solution: 1. Young physical activity enthusiasts 2. all-round healthy behaviours 3. low on fruit and vegetable and physical activity 4. Energy-dense eaters who watch 5. Screen-time focused	Not associated
Carson, 2015	- Physical activity (moderate and hard) - screen time (TV, internet, video/computer games) - sleep	13-18 years Canada	Latent class analysis	3 underlying subgroups: 1. 'healthiest movers' 2. 'active screenies' 3. 'unhealthiest movers'	Active screenies and unhealthiest movers more likely to be overweight or obese compared to the healthiest movers (especially among females)
de la Haye, 2014	- Alcohol, cigarette and marijuana use - Physical inactivity - Sedentary (screen-time) behaviours - Consumption of low nutrient, energy dense food	Grade 6-8 California	Confirmatory factor analysis to assess for underlying factors that account for covariance of multiple behaviours Also measured composite reliability to determine the	Behaviours explained by 2 (distinct) moderately correlated factors 1. substance use risk factor 2. unhealthy eating and sedentary factor * physical activity variable did not relate to the	Did not assess

			degree to which the behaviours were related	underlying risk factors	
Dodd, 2010	- Psychological stress - Physical activity - Fruit and vegetable intake - Binge drinking and smoking	Mean age 22.8 years United Kingdom	2-step cluster analysis procedure Chi-square and ANOVA to identify differences between clusters and demographic characteristics	Three distinct clusters: 1. unhealthy/high risk group → high psychological stress, low physical activity, low fruit and vegetable consumption, high smoking 2. moderately healthy/moderate risk group → moderate psychological stress, physical activity, and fruit and vegetable intake (+ higher binge drinking and smoking) 3. Healthy/low risk → low psychological stress, high physical activity, high fruit and vegetable intake, moderate alcohol consumption, and non-smokers	Did not assess
Ferrar, 2013	- sleep - screen-time - social interaction - eating - play - sports - reading/homework - active transport	10-16 years New Zealand	Cluster analysis	Boys: 1. techno-active 2. quiet movers 3. social studious Girls: 1. Social sporty 2. Screenie-tasker 3. super studious	Super studious (girls) cluster was over-represented by normal weight participants. More social sporty members were overweight or obese
Gorely, 2007	- TV/video, computer/Internet - sports/exercise - socializing behaviours (hanging out/sitting/phone)	Mean age 14.7 years United Kingdom	Two-stage cluster analysis to identify patterns of leisure time behaviour	5 cluster solutions: Boys – 1. Sedentary homeworkers 2. Semi-active socializers	Did not assess

	- homework - work (paid + chores)		Discriminant analysis to examine cluster profiles on key explanatory variables	3. Sedentary TV watchers 4. Actives 5. Sedentary computer users Girls – 1. Sedentary homeworkers 2. Sedentary socializers 3. Sedentary TV watchers 4. Actives 5. Sedentary workers	
Hardy, 2012	- Physical activity - screen time - fruit and vegetable consumption - soft drink and snack consumption	Grades 6, 8, and 10 New South Wales, Australia	Tested co-occurrence using an observed-to-expected ratio method	- 5% of boys and 9% of girls reported no obesogenic lifestyle risk factors - the most prevalent pattern of co-occurrence was among girls – low fruit and vegetables, high screen time, and high intake of snacks and soft drinks	
Heitzler, 2011	- physical activity (sports, activities, chores/work) - sedentary behaviour (TV/DVD, video games, internet, talking/texting, reading/homework)	11-17 years Minnesota	Latent class analysis Multinomial logistic regression to examine difference in class memberships	Boys: 1. Active 2. High screen-media and high-homework 3. low media/moderate activity Girls: 1. active 2. sedentary class (high screen media use) 3. low media/functional activity	Boys in the sedentary class were more likely to be overweight than those in the Active class; similarly, higher proportion of girls in the sedentary class were classified as overweight
Huh, 2011	- Physical activity - eating behaviours - sedentary behaviour - weight perception	4th grade Southern California	Latent class analysis	5-class solution: 1. high-sedentary, high fat and sugar snacks, weight not conscious 2. dieting without exercise, weight conscious	Overweight/obese were associated with latent class membership – obesity was observed in class 1 and class 2 over the

				3. high-sedentary, high fat and sugar snacks, weight conscious 4. active, healthy eating 5. low healthy, snack food, inactive, not weight conscious	others
Iannotti, 2013	- Physical activity - screen-based sedentary behaviour - frequency of consumption of healthy and unhealthy foods - weight status - weight control behaviour - depression - physical symptoms - body dissatisfaction - overall health - life satisfaction	11-16 years United States	Latent class analysis to identify patterns of behaviours	Model with three latent classes best fit the data: 1. high PA, high fruit and vegetable, low SB, low intake of sweets, soft drinks, chips and fries 2. high SB and high intake of sweets, soft drinks, chips and fries 3. low PA, low fruit and vegetable, low intake of sweets, chips, and fries	Class 1 most likely to be of normal weight status
Jago, 2010	Accelerometer and self-reported time spent in physical activity or sedentary behaviours	10-11 years	Cluster analysis	3 clusters emerged: 1. high active/low sedentary 2. low active/moderate sedentary 3. high active/high sedentary	Did not assess
Kim, 2016	- subjectively measured physical activity - screen-based sedentary behaviour	Adolescents	Latent class analysis	4 latent subgroups 1. High physical activity, high sedentary behaviour 2. High physical activity, low sedentary behaviour 3. Low physical activity, high sedentary behaviour 4. Low physical activity, low sedentary behaviour	Likelihood of being obese was significantly greater for the subgroups with low PA or high SB compared to the high PA/low SB group across genders Low PA/High SB had greater likelihood of being obese
Landsberg, 2010	- Physical activity - modes of commuting to school	14 years	Two-step cluster analysis approach	3 lifestyle clusters: 1. low-activity and low-	Prevalence of obesity was the lowest in

	- media time - nutrition - alcohol consumption and smoking	Kiel, Germany		risk behaviour cluster 2. high media time and high-risk behaviour cluster 3. high activity and medium-risk behaviour	cluster 3
Leech, 2014b	- Diet - physical activity - sedentary behaviour	5-6 and 10-12 year olds Australia	K-means cluster analysis, chi-square tests to assess cluster differences	3 reliable and meaningful clusters: 1. 'most healthy' 2. 'energy-dense consumers who watch TV' 3. 'highly sedentary behaviour/low MVPA'	Did not assess
Leech, 2014a	Review article on clustering patterns of diet, physical activity, and sedentary behaviours	• Cluster analysis • Latent class analysis Most robust finding – tendency for older children/adolescents (mostly females) to belong to clusters that include low PA			Inconclusive: **longitudinal research needed**
Liu, 2010	- Physical activity - sedentary behaviour	Grades 7-12 United States	Latent class analysis (gender specific) Logistic regression models to predict odds of meeting MVPA and screen-time guidelines 6 years later, based on class profile	5 classes for each gender: 1. low PA/low SED 2. moderate PA/high SED 3. Moderate PA/low SED 4. high PA/low SED 5. high PA (except skating/biking)/low SED	Did not assess
Marshall, 2002	- 32 physical activities - 7 sedentary activities (in the last 7 days)	11-15 years United States and United Kingston	Gender-specific cluster analysis	3 similar clusters for both boys and girls: 1. 'techno-active' for boys and 'sociable active' for girls 2. non-socializing actives 3. uninvolved inactives	Not associated
Mistry, 2009	- Smoking - alcohol use - fruit and vegetable consumption - physical activity	14.5 years California	Gender-specific cluster analysis (k-means cluster analysis)	4 clusters: 1. Salutary adherent (no risk behaviours) 2. Active snackers (active, low fruit/vegetables) 3. Sedentary snacker	Did not assess

				(inactive, low fruit/vegetable) 4. Risk takers (smoker, alcohol user, physically inactive, low fruit/vegetables)	
Monda, 2005	- physical activity (gym in school, team sports in school, track/swimming in school, active commuting) - sedentary variables (TV/video and reading/writing/drawing/homework)	6-18 years China	Cluster analysis	6 clusters: 1. moderate PA/moderate sed 2. moderate PA/high sed 3. high PA/high sed 4. low PA/moderate Sed 5. low PA/high sed 6. low PA/no sed	Significant reduction in odds of overweight among those with moderate or high levels of activity
Nelson, 2005	- housework - hobbies - active play - sports/exercise, - school physical education - sports and academic clubs - use of neighbourhood recreation centres - watching TV/videos - playing video/computer games - sports with parents - parent-regulated TV	Grades 7-12 United States	Cluster analysis	7 clusters: 1. high TV/video, video game 2. high skating, video game 3. high sports 4. use of rec centres, high sports 5. TV viewing limited by parents, moderate school PE 6. low parental TV control, few activities 7. active in school	Did not look at obesity; rather, at odds of meeting physical activity recommendations – highest for clusters 2, 3, 4 and 7
Ottevaere, 2011	- Physical activity - sedentary behaviour - dietary behaviours	12.5-17.5 years Europe	Cluster analysis, chi-square to assess gender differences	5 stable and meaningful clusters: 1. Unhealthy 2. Sedentary 3. Active, low diet quality 4. Inactive, high diet quality 5. Healthy	No significant differences in BMI across the clusters
Plotnikoff, 2009	- Physical activity - dietary intake - smoking	11-17 years Canada	Trend analyses to examine potential linear trends	50% of youth had 2+ risk factors for chronic conditions	Did not assess

	- BMI		between age and the risk factors separately Primary risk factor clusters (0, 1, 2, 3, 4, 5) examined by aggregating across risk factors. Bivariate correlations examined clustering of risk factors.		
Sabbe, 2008	- MVPA - consumption of sugar and/or fat - meeting food pyramid recommendations	10 years Netherlands	K-means cluster analysis, chi-square to confirm associations between clusters and socio-demographic factors including overweight	5 cluster solution: 1. Sporty healthy eaters 2. Sporty mixed eaters 3. Moderate active healthy eaters 4. Non-sporty unhealthy eaters 5. Sedentary healthy eaters	No association with weight status
Sanchez, 2007	- Physical activity - television viewing time - percent calories from fat - servings of fruit and vegetable consumption	11-15 years Primary care clinics in San Diego	Total risk behaviour score based on the total number of unmet guidelines	Only 2% of adolescents met all guidelines; 48% of the sample had more than three factors. The most prevalent behavioural cluster was insufficient activity and not meeting dietary recommendations for fat and fruits and vegetables.	Higher number of risk factors associated with overweight
Seghers, 2010	- Physical activity - sedentary behaviour - food habits	11-12 years Netherlands	K-means cluster analysis to identify patterns in the behaviour indices	4 reliable and meaningful clusters emerged: 1. Sporty media-oriented mixed eaters 2. Academic healthy eaters 3. Inactive healthy eaters 4. Inactive media-oriented unhealthy eaters	No association with weight status
te Velde,	- Usual TV viewing and computer use	11 years	Cluster analysis	5 cluster solution:	Boys and girls in low

2007	- TV viewing during dinner - physical activity	9 countries in Europe		1. Healthy behaviour pattern 2. High TV viewers 3. Low sedentary behaviour and low physical activity (for girls, mixed for boys) 4. High PC users 5. Unhealthy behaviour pattern (high sedentary, below average physical activity)	PA/high SB cluster, and the high TV cluster have the highest odds of overweight
Turner, 2011	- MVPA - sedentary behaviour (TV/video, computer/Internet, homework, talking with friends) - fruit and vegetable consumption - alcohol use	14-17 year olds Toronto, Canada	Two-step cluster analysis * variable importance plots to show behaviours that contribute most to each cluster, can be used as a guideline to interpret cluster solutions	3 clusters: 1. Active, high screen-time users 2. Active, low screen-time users 3. Less active, least frequent drinkers	No association
van der Sluis, 2010	- fruit and vegetable consumption - sugar-sweetened beverage and snack consumption - sedentary behaviour - physical activity	Students in grades 6 and 7 Norway	K-means cluster analysis and linear regression	4 clusters 1. 'Healthy' – high fruit and vegetable, low sugar sweetened beverage and snack, low time in sedentary behaviour, and high PA 2.'Quite healthy' – medium FV, low SS consumption, medium SB, and relatively high PA 3. 'Quite unhealthy' – low FV, SS, high sedentary behaviour and medium PA 4. 'Unhealthy'- low FV, high SS, high SB, and low	Unhealthy cluster was significantly negatively related to BMI, no other clusters were related (unexpected association)

				PA	

*Most clusters could not be identified by weight status, so it is important to screen individual health behaviours and their association with BMI trajectories (paper 2)

Table 11. Longitudinal studies on youth behaviours and overweight/obesity

Study	**Setting**	**Design**	**Age**	**Behaviours**	**Methods**	**Results**
Berkey, 2000	US	Pre-post 1 year	9-14 years at baseline	Physical activity, recreational activities, and dietary patterns	Linear regression models with 1-year change in BMI as a continuous outcome variable - controlled for race/ethnic group, baseline BMI, annual change in height, menstrual history, Tanner stage, and age	Larger increase in BMI over one year for girls that reported higher caloric intake, lower physical activity, and more screen-time. Larger BMI increase among boys that reported more screen-time * Although the magnitudes of estimated effects were small, year-to-year increases would produce substantial gains
Berkey, 2003a	US	Pre-post 1 year change	10-15 years	Recreational physical activity and inactivity (TV/videos)	Regression models with change in BMI as a continuous outcome	Increase in physical activity associated with decreasing relative BMI in girls and in overweight boys Increase in inactivity associated with increasing BMI in girls.
Berkey, 2003b	US	Annual follow up for 3 years	9-14 years at baseline	Breakfast consumption	Mixed linear regression models, with annual change in BMI as a continuous outcome variable Models estimated using generalized estimating equations to account for repeated measures for each student	- Never breakfast eaters had lower energy intakes - Skipping breakfast was associated with overweight (cross-sectional) - Overweight children that never ate breakfast had a decrease in BMI over one year, compared to overweight children that ate breakfast daily. - Normal weight children that never ate breakfast gained weight relative to those that ate breakfast

						daily
Boone, 2007	US (representative sample)	Grades 7-12 followed into adulthood	15.9-21.4	Physical activity and screen time	Logistic regression to assess correlates of adolescent obesity and predictors of obesity incidence from adolescence to young adulthood	Males: prevalent obesity was predicted by MVPA (OR 0.50, 95% CI 0.40-0.62). Females: greater MVPA (OR 0.67, 95% CI 0.49-0.91) and lower screen time (OR 0.67, 95% CI 0.53-0.85) correlated with lower obesity Longitudinally – adolescent screen time had a stronger influence on incident obesity in females (OR 0.58, 95% CI 0.43-0.80) compared to males (OR 0.78, 95% CI 0.61-0.99)
Elgar, 2005	Wales	Pre-post 4 years	12.3 years at baseline	Physical activity and sports; screen-time	Multiple linear regression, adjusting for sex, age, baseline BMI, family size, SES, eating habits	Each additional hour/week of exercise was associated with a decrease in BMI
Falbe, 2014	US	2-year changes in foods of low nutritional quality	9-16 years at baseline	Screen-time (TV, electronic games, DVDs/videos, total screen time)	Multivariate linear regression models, using generalized estimating equations to account for repeated measures	Each hour per day increase in screen-time was associated with increased intake of sugar-sweetened beverages, fast food, sweets, and salty snacks, and decreased intake of fruit and vegetables
Field, 2003	US	Annual follow-up for 3 years	9-14 years at baseline	Fruit and vegetable intake	Modeled for change in age- and gender-specific z-score of BMI	Annual changes in BMI were slightly greater among boys than girls. No relation between intake of fruit, fruit juice, or vegetables and change in BMI (among girls). Among boys, intake of fruit and fruit juice not predictive of weight change, but vegetable intake was inversely related to change in BMI (effect diminished after controlling for caloric intake)
Foster, 2008	US	Baseline	Grades 4	BMI z-score, total	Policy randomly assigned to	Incidence of overweight/obesity

		and after 2 years	through 6	energy and fat intake, fruit and vegetable consumption, body dissatisfaction, and hours of activity/inactivity	intervention schools; control schools matched on size and type of food services.	after 2 years was significantly lower (50% reduction); fewer children in intervention schools became overweight after 2 years compared to control schools
Gordon-Larsen, 2002	US	Pre-post 1 year	12-22 years	Physical activity, screen-time	Logistic regression for obese, adjusting for age, ethnicity, SES, urban, smoking, and region	Boys – OR for overweight 0.86 with additional MVPA/week, 1.48 with >35h/week of screen-time Girls – OR for overweight 0.90 with additional MVPA/week, 1.43 with more screen time
Kettaneh, 2005	Northern France	Pre-post 5 years	8-18 years	Physical activity (pedometer and self-report)	Multiple linear regression predicting adiposity, adjusted for baseline adiposity, pubertal stage, and age	In girls, higher level of moderate activity was associated with higher adiposity
Koning, 2016	Zwolle, the Netherlands	6 years, measured in 2006, 2009, and 2012	4-12 years	Health-related behaviours at all three years by parental report. Weight measured at all three years	Logistic regression to identify association between behaviour and weight	2 BMI trajectories – decreasing and increasing. Increasing trajectory consisted of more participants with low SES and non-western ethnicity, as well as more sugary drinks, less participation in organized sport (only significant result), more TV viewing
Ludwig, 2001	Massachussets	19 months	11-17 years	Baseline and change in consumption of sugar-sweetened beverages	Linear and logistic regression analyses, adjusting for potentially confounding variables and clustering within schools	Each additional serving was associated with an increase in BMI and frequency of BMI
Mitchell, 2013	10 geographic locations in the US	2nd and 3rd year follow up	9, 11, 12, and 15 years	Sedentary behaviour and physical activity	Longitudinal quintile regression to model influence of predictors on changes in BMI percentile over time	Sedentary behaviour associated with greater increase in BMI at 90th, 75th, and 50th percentiles between 9 and 15 years of age, independent of MVPA
Phillips, 2004	Cambridge, MA	Followed until 4 years after menarche	8-12 years	% body fat, BMI z-score and dietary intake	Linear mixed effects modeling	No relationship between energy-dense snack food and BMI z-score or body fat percentage Soda significantly related to BMI z-score over 1-years

		(~10 years)				
Robinson, 1993	Northern California	7, 14, 24 months	12.4 years at baseline	After-school TV	Hierarchical multiple linear regression for change in body composition, adjust for baseline confounders	Baseline TV was not related to change in adiposity in adolescent girls
Trang, 2012	Ho Chi Minh City, Vietnam	5-year follow-up, assessed each year	Junior high school	Environmental and lifestyle behaviours on overweight and obesity	In the future: To assess relationship between exposure and change in BMI, will use mixed multiple regression models to adjust for clustering and repeated measures	Overweight and obesity increased from 14.2-21.8% over the 5 years; time spent in physical activity decreased.
van der Sluis, 2010	Norway	1- and 4-year follow-ups	Average 11.8 years	Four energy balance-related behaviours: fruit and vegetable consumption, sugar-sweetened beverage and snack consumption, sedentary behaviour, and physical activity	Longitudinal multi-level mixed model logistic regression - dichotomized behaviours into high-risk vs. low-risk behaviours - adjusted models for school and time - included time interaction to evaluate if associations remained stable over time ($p<0.10$)	Risk behaviours were associated Boys: low fruit and vegetable intake was associated with a 1.75 increased odds for high sugar sweetened beverage ad snack consumption

Appendix C: COMPASS Student Questionnaire (Cq)

Compass

- **This is NOT a test**. All of your answers will be kept **confidential**. No one, not even your parents or teachers, will ever know what you answered. So, please be honest when you answer the questions.
- Mark only **one option per question** unless the instructions tell you to do something else.
- Choose the option that is the **closest** to what you think/feel is true for you.

Please, use a pencil to complete this questionnaire

Please mark all your answers with full, dark marks like this: ○ ● ○ ○

START HERE

Please read each sentence below carefully. Write the correct letter, number, or word on the line and then fill in the corresponding circle.

The first letter of your **middle** name (if you have more than one middle name use your first middle name; if you don't have a middle name use "Z"):____	The name of the month in which you were born: ________	The **last** letter of your full **last** name: ___	The **second** letter of your full **first** name: ___	The **first** initial of your **mother's** first name (think about the mother you see the most):___
Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ Ⓙ Ⓚ Ⓛ Ⓜ Ⓝ Ⓞ Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ Ⓤ Ⓥ Ⓦ Ⓧ Ⓨ Ⓩ	① January ② February ③ March ④ April ⑤ May ⑥ June ⑦ July ⑧ August ⑨ September ⑩ October ⑪ November ⑫ December	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ Ⓙ Ⓚ Ⓛ Ⓜ Ⓝ Ⓞ Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ Ⓤ Ⓥ Ⓦ Ⓧ Ⓨ Ⓩ	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ Ⓙ Ⓚ Ⓛ Ⓜ Ⓝ Ⓞ Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ Ⓤ Ⓥ Ⓦ Ⓧ Ⓨ Ⓩ	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ Ⓙ Ⓚ Ⓛ Ⓜ Ⓝ Ⓞ Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ Ⓤ Ⓥ Ⓦ Ⓧ Ⓨ Ⓩ

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COMPASS Questionnaire

About You

1. What grade are you in?

- ○ Grade 9
- ○ Grade 10
- ○ Grade 11
- ○ Grade 12

2. How old are you today?

- ○ 13 years or younger
- ○ 14 years
- ○ 15 years
- ○ 16 years
- ○ 17 years
- ○ 18 years or older

3. Are you female or male?

- ○ Female
- ○ Male

4. How would you describe yourself? *(Mark all that apply)*

- ○ White
- ○ Black
- ○ Asian
- ○ Aboriginal (First Nations, Métis, Inuit)
- ○ Latin American/Hispanic
- ○ Other _____

5. About how much money do you usually get each week to spend on yourself or to save?
(Remember to include all money from allowances and jobs like baby-sitting, delivering papers, etc.)

- ○ Zero
- ○ $1 to $5
- ○ $6 to $10
- ○ $11 to $20
- ○ $21 to $40
- ○ $41 to $100
- ○ More than $100
- ○ I do not know how much money I get each week

6. How do you usually travel to and from school? *(If you use two or more modes of travel, choose the one that you spend most time doing)*

To school	From school
○ By car (as a passenger)	○ By car (as a passenger)
○ By car (as a driver)	○ By car (as a driver)
○ By school bus	○ By school bus
○ By public bus, subway, or streetcar	○ By public bus, subway, or streetcar
○ By walking	○ By walking
○ By bicycling	○ By bicycling
○ Other_____	○ Other_____

7. Did you attend this school last year?

- ○ Yes, I attended the same school last year
- ○ No, I was at another school last year

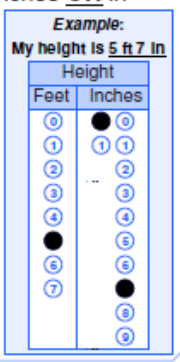
8. How tall are you without your shoes on? (Please write your height in feet and inches **OR** in centimetres, and then fill in the appropriate numbers for your height.)

○ **I do not know how tall I am**

"My height is ____feet, _____inches"

OR

"My height is _____ centimetres"



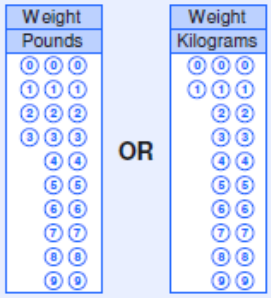
9. How much do you weigh without your shoes on? (Please write your weight in pounds **OR** in kilograms, and then fill in the appropriate numbers for your weight.)

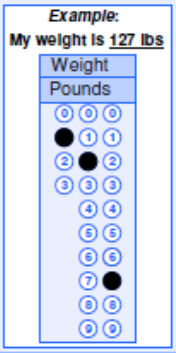
○ **I do not know how much I weigh**

"My weight is _____ pounds"

OR

"My weight is _____ kilograms"





10. How much time per day do you *usually* spend doing the following activities?

For example: If you spend about 3 hours watching TV each day, you will need to fill in the 3 hour circle, and the 0 minute circle as shown below:

a) Watching/streaming TV shows or movies — **Hours** ○ ○ ○ ● ○ ○ ○ ○ ○ ○ **Minutes** ● ○ ○ ○

	Hours	Minutes
a) Watching/streaming TV shows or movies	○ ○ ○ ○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○
b) Playing video/computer games	○ ○ ○ ○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○
c) Doing homework	○ ○ ○ ○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○
d) Talking on the phone	○ ○ ○ ○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○
e) Surfing the internet	○ ○ ○ ○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○
f) Texting, messaging, emailing **(note: 50 texts = 30 minutes)**	○ ○ ○ ○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○
g) Sleeping	○ ○ ○ ○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○

○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

Physical Activity

HARD physical activities include jogging, team sports, fast dancing, jump-rope, and any other physical activities that increase your heart rate and make you breathe hard and sweat.

MODERATE physical activities include lower intensity activities such as walking, biking to school, and recreational swimming.

11. Mark how many minutes of HARD physical activity you did on each of the last 7 days. This includes physical activity during physical education class, lunch, after school, evenings, and spare time.

	Hours					Minutes				
Monday	○	○	○	○	○	○	○	○	○	○
Tuesday	○	○	○	○	○	○	○	○	○	○
Wednesday	○	○	○	○	○	○	○	○	○	○
Thursday	○	○	○	○	○	○	○	○	○	○
Friday	○	○	○	○	○	○	○	○	○	○
Saturday	○	○	○	○	○	○	○	○	○	○
Sunday	○	○	○	○	○	○	○	○	○	○

For example: If you did 45 minutes of hard physical activity on Monday, you will need to fill in the 0 hour circle and the 45 minute circle, as shown below:

	Hours					Minutes				
Monday	●	○	○	○	○	○	○	○	●	

12. Mark how many minutes of MODERATE physical activity you did on each of the last 7 days. This includes physical activity during physical education class, lunch, after school, evenings, and spare time. Do not include time spent doing hard physical activities.

	Hours					Minutes				
Monday	○	○	○	○	○	○	○	○	○	○
Tuesday	○	○	○	○	○	○	○	○	○	○
Wednesday	○	○	○	○	○	○	○	○	○	○
Thursday	○	○	○	○	○	○	○	○	○	○
Friday	○	○	○	○	○	○	○	○	○	○
Saturday	○	○	○	○	○	○	○	○	○	○
Sunday	○	○	○	○	○	○	○	○	○	○

For example: If you did 1 hour and 30 minutes of moderate physical activity on Monday, you will need to fill in the 1 hour circle and the 30 minute circle, as shown below:

	Hours					Minutes				
Monday	○	●	○	○	○	○	○	●	○	

13. Were the last 7 days a typical week in terms of the amount of physical activity that you usually do?

- ○ Yes
- ○ No, I was *more* active in the last 7 days
- ○ No, I was *less* active in the last 7 days

14. Your closest friends are the friends you like to spend the most time with. How many of your closest friends are physically active?

- ○ None
- ○ 1 friend
- ○ 2 friends
- ○ 3 friends
- ○ 4 friends
- ○ 5 or more friends

15. Are you taking a physical education class at school this year?

- ○ **Yes**, I am taking one **this term**
- ○ **Yes**, I will be taking one or have taken one this school year, **but not this term**.
- ○ **No**, I am not taking a physical education class at school this year

16. **Do you participate in before-school, noon hour, or after-school physical activities organized by your school?** *(e.g., intramurals, non-competitive clubs)*

- ○ Yes
- ○ No
- ○ None offered at my school

17. **Do you participate in competitive school sports teams that compete against other schools?** *(e.g., junior varsity or varsity sports)*

- ○ Yes
- ○ No
- ○ None offered at my school

18. **Do you participate in league or team sports outside of school?**

- ○ Yes
- ○ No
- ○ There are none available where I live

19. **On how many days in the last 7 days did you do exercises to strengthen or tone your muscles?** *(e.g., push-ups, sit-ups, or weight-training)*

- ○ 0 days
- ○ 1 day
- ○ 2 days
- ○ 3 days
- ○ 4 days
- ○ 5 days
- ○ 6 days
- ○ 7 days

20. **How do <u>you</u> describe your weight?**

- ○ Very underweight
- ○ Slightly underweight
- ○ About the right weight
- ○ Slightly overweight
- ○ Very overweight

21. **Which of the following are you trying to do about your weight?**

- ○ **Lose** weight
- ○ **Gain** weight
- ○ **Stay** the same weight
- ○ I am **not trying to do anything** about my weight

22. **How much do your parents, step-parents, or guardians encourage you to be physically active?**

- ○ Strongly encourage
- ○ Encourage
- ○ Do not encourage or discourage
- ○ Discourage
- ○ Strongly discourage

23. **How much do your parents, step-parents, or guardians support you in being physically active?** *(e.g., driving you to team games, buying you sporting equipment)*

- ○ Very supportive
- ○ Supportive
- ○ Unsupportive
- ○ Very unsupportive

○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

Healthy Eating

24. If you do not eat breakfast every day, why do you skip breakfast? *(Mark all that apply)*

- ○ I eat breakfast every day
- ○ I don't have time for breakfast
- ○ The bus comes too early
- ○ I sleep in
- ○ I'm not hungry in the morning
- ○ I feel sick when I eat breakfast
- ○ I'm trying to lose weight
- ○ There is nothing to eat at home
- ○ Other _____

25. In a *usual* school week *(Monday to Friday)*, on how many days do you do the following?

	None	1 day	2 days	3 days	4 days	5 days
a) Eat breakfast	○	○	○	○	○	○
b) Eat breakfast provided to you **as part of a school program**	○	○	○	○	○	○
c) Eat lunch at school - lunch packed and brought from home	○	○	○	○	○	○
d) Eat lunch at school - lunch purchased in the cafeteria	○	○	○	○	○	○
e) Eat lunch purchased at a fast food place or restaurant	○	○	○	○	○	○
f) Eat snacks purchased from a vending machine **in your school**	○	○	○	○	○	○
g) Eat snacks purchased from a vending machine, corner store, snack bar, or canteen **off school property**	○	○	○	○	○	○
h) Drink sugar-sweetened beverages (soda pop, Kool-Aid, Gatorade, etc.) Do not include diet/sugar-free drinks	○	○	○	○	○	○
i) Drink high-energy drinks (Red Bull, Monster, Rock Star, etc.)	○	○	○	○	○	○
j) Drink coffee or tea **with sugar** (include cappuccino, frappuccino, iced-tea, iced-coffees, etc.)	○	○	○	○	○	○
k) Drink coffee or tea **without sugar**	○	○	○	○	○	○

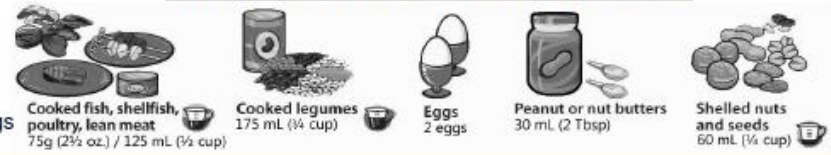
26. On a *usual* weekend *(Saturday and Sunday)*, on how many days do you do the following?

	None	1 day	2 days
a) Eat breakfast	○	○	○
b) Eat lunch	○	○	○
c) Eat foods purchased at a fast food place or restaurant	○	○	○
d) Eat snacks purchased from a vending machine, corner store, snack bar, or canteen	○	○	○
e) Drink sugar-sweetened beverages (soda pop, Kool-Aid, Gatorade, etc.) Do not include diet/sugar-free drinks	○	○	○
f) Drink high energy drinks (Red Bull, Monster, Rock Star, etc.)	○	○	○
g) Drink coffee or tea **with sugar** (include cappuccino, frappuccino, iced-tea, iced-coffees, etc.)	○	○	○
h) Drink coffee or tea **without sugar**	○	○	○

27. **YESTERDAY**, ***from the time you woke up until the time you went to bed***, **how many servings of meats and alternatives did you have?** *One 'Food Guide' serving of meat and alternatives includes cooked fish, chicken, beef, pork, or game meat, eggs, nuts or seeds, peanut butter or nut butters, legumes (beans), and tofu.*

- ○ None
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 or more servings

Canada's Food Guide **Serving Sizes of Meats and Alternatives**



28. **YESTERDAY**, ***from the time you woke up until the time you went to bed***, **how many servings of vegetables and fruits did you have?** *One 'Food Guide' serving of vegetables and fruit includes pieces of fresh vegetable or fruit, salad or raw leafy greens, cooked leafy green vegetables, dried or canned or frozen fruit, and 100% fruit or vegetable juice.*

- ○ None
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 servings
- ○ 6 servings
- ○ 7 servings
- ○ 8 servings
- ○ 9 or more servings

Canada's Food Guide **Serving Sizes of Vegetables and Fruits**

29. **YESTERDAY**, ***from the time you woke up until the time you went to bed***, **how many servings of milk and alternatives did you have?** *One 'Food Guide' serving of milk or milk alternatives includes milk, fortified soy beverage, reconstituted powdered milk, canned (evaporated) milk, yogurt or kefir (another type of cultured milk product), and cheese.*

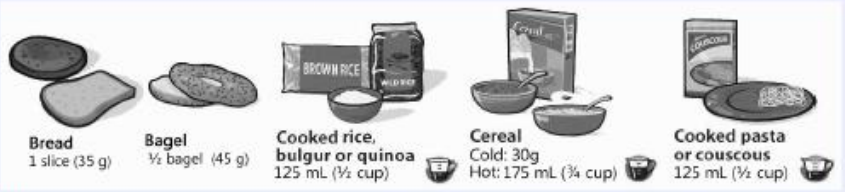
- ○ None
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 servings
- ○ 6 or more servings

Canada's Food Guide **Serving Sizes of Milk and Alternatives**

30. **YESTERDAY**, ***from the time you woke up until the time you went to bed***, **how many servings of grain products did you have?** *One 'Food Guide' serving of grain products includes bread, bagels, flatbread such as tortilla, pita, cooked rice or pasta, and cold cereal.*

- ○ None
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 servings
- ○ 6 servings
- ○ 7 servings
- ○ 8 servings
- ○ 9 or more servings

Canada's Food Guide **Serving Sizes of Grain Products**



Your Experience with Smoking

31. Have you ever tried cigarette smoking, even just a few puffs?

- ○ Yes
- ○ No

32. How old were you when you first tried smoking cigarettes, even just a few puffs?

- ○ I have never done this
- ○ I do not know

- ○ 8 years or younger
- ○ 9 years
- ○ 10 years
- ○ 11 years
- ○ 12 years
- ○ 13 years
- ○ 14 years
- ○ 15 years
- ○ 16 years
- ○ 17 years
- ○ 18 years or older

33. Do you think in the future you might try smoking cigarettes?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

34. If one of your best friends were to offer you a cigarette, would you smoke it?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

35. At any time during the next year do you think you will smoke a cigarette?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

36. Do you think it would be difficult or easy for you to get cigarettes if you wanted to smoke?

- ○ Difficult
- ○ Easy
- ○ I do not know

37. Have you ever smoked a whole cigarette?

- ○ Yes
- ○ No

38. Have you ever smoked 100 or more whole cigarettes in your life?

- ○ Yes
- ○ No

○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

39. **Have you ever smoked every day for at least 7 days in a row?**
- ○ Yes
- ○ No

40. **On how many of the last 30 days did you smoke one or more cigarettes?**
- ○ None
- ○ 1 day
- ○ 2 to 3 days
- ○ 4 to 5 days
- ○ 6 to 10 days
- ○ 11 to 20 days
- ○ 21 to 29 days
- ○ 30 days *(every day)*

41. **Thinking back over the last 30 days, on the days that you smoked, how many cigarettes did you usually smoke each day?**
- ○ None
- ○ A few puffs to one whole cigarette
- ○ 2 to 3 cigarettes
- ○ 4 to 5 cigarettes
- ○ 6 to 10 cigarettes
- ○ 11 to 20 cigarettes
- ○ 21 to 29 cigarettes
- ○ 30 or more cigarettes

42. **Your closest friends are the friends you like to spend the most time with. How many of your closest friends smoke cigarettes?**
- ○ None
- ○ 1 friend
- ○ 2 friends
- ○ 3 friends
- ○ 4 friends
- ○ 5 or more friends

43. **Have you ever tried to quit smoking cigarettes?**
- ○ I have never smoked
- ○ I have only smoked a few times
- ○ I have never tried to quit
- ○ I have tried to quit once
- ○ I have tried to quit 2 or 3 times
- ○ I have tried to quit 4 or 5 times
- ○ I have tried to quit 6 or more times

44. **In the last 30 days, did you use any of the following?** *(Mark all that apply)*
- ○ Pipe tobacco
- ○ Cigarillos or little cigars (*plain or flavoured*)
- ○ Cigars (not including cigarillos or little cigars, *plain or flavoured*)
- ○ Roll-your-own cigarettes (tobacco only)
- ○ Loose tobacco mixed with marijuana
- ○ E-cigarettes (electronic cigarettes that look like cigarettes/cigars, but produce vapour instead of smoke)
- ○ Smokeless tobacco (chewing tobacco, pinch, snuff, or snus)
- ○ Nicotine patches, nicotine gum, nicotine lozenges, or nicotine inhalers
- ○ Hookah (water-pipe) to smoke tobacco
- ○ Hookah (water-pipe) to smoke herbal sheesha/shisha
- ○ Blunt wraps (a sheet or tube made of tobacco used to roll cigarette tobacco)
- ○ I have not used any of these things in the last 30 days

Alcohol and Marijuana Use

*Please remember that we will keep your answers **completely confidential**.*

A **DRINK** means: 1 regular sized bottle, can, or draft of beer; 1 glass of wine; 1 bottle of cooler; 1 shot of liquor (rum, whiskey, etc); or 1 mixed drink (1 shot of liquor with pop, juice, energy drink).

45. In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?

- ○ I have never drunk alcohol
- ○ I did not drink alcohol in the last 12 months
- ○ I have only had a sip of alcohol
- ○ Less than once a month
- ○ Once a month
- ○ 2 or 3 times a month
- ○ Once a week
- ○ 2 or 3 times a week
- ○ 4 to 6 times a week
- ○ Every day

46. How old were you when you first had a drink of alcohol that was more than just a sip?

- ○ I have never drunk alcohol
- ○ I have only had a sip of alcohol
- ○ I do not know

- ○ 8 years or younger
- ○ 9 years
- ○ 10 years
- ○ 11 years
- ○ 12 years
- ○ 13 years
- ○ 14 years
- ○ 15 years
- ○ 16 years
- ○ 17 years
- ○ 18 years or older

47. In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?

- ○ I have never done this
- ○ I did not have 5 or more drinks on one occasion in the last 12 months
- ○ Less than once a month
- ○ Once a month
- ○ 2 to 3 times a month
- ○ Once a week
- ○ 2 to 5 times a week
- ○ Daily or almost daily

48. In the last 12 months, have you had alcohol mixed or pre-mixed with an energy drink (such as Red Bull, Rock Star, Monster, or another brand)?

- ○ I have never done this
- ○ I did not do this in the last 12 months
- ○ Yes
- ○ I do not know

49. In the last 12 months, how often did you use marijuana or cannabis? (a joint, pot, weed, hash)

- ○ I have never used marijuana
- ○ I have used marijuana but not in the last 12 months
- ○ Less than once a month
- ○ Once a month
- ○ 2 or 3 times a month
- ○ Once a week
- ○ 2 or 3 times a week
- ○ 4 to 6 times a week
- ○ Every day

50. How old were you when you first used marijuana or cannabis?

- ○ I have never used marijuana
- ○ I do not know

- ○ 8 years or younger
- ○ 9 years
- ○ 10 years
- ○ 11 years
- ○ 12 years
- ○ 13 years
- ○ 14 years
- ○ 15 years
- ○ 16 years
- ○ 17 years
- ○ 18 years or older

51. Do you think it would be difficult or easy for you to get marijuana if you wanted some?

- ○ Difficult
- ○ Easy
- ○ I do not know

○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

Your School and You

52. How strongly do you agree or disagree with each of the following statements?

	Strongly Agree	Agree	Disagree	Strongly Disagree
a) I feel close to people at my school.	○	○	○	○
b) I feel I am part of my school.	○	○	○	○
c) I am happy to be at my school.	○	○	○	○
d) I feel the teachers at my school treat me fairly.	○	○	○	○
e) I feel safe in my school.	○	○	○	○
f) Getting good grades is important to me.	○	○	○	○

53. In the last 30 days, in what ways were you bullied by other students? *(Mark all that apply)*

- ○ I have not been bullied in the last 30 days
- ○ Physical attacks (e.g., getting beaten up, pushed, or kicked)
- ○ Verbal attacks (e.g., getting teased, threatened, or having rumours spread about you)
- ○ Cyber-attacks (e.g., being sent mean text messages or having rumours spread about you on the internet)
- ○ Had someone steal from you or damage your things

54. In the last 30 days, how often have you been bullied by other students?

- ○ I have not been bullied by other students in the last 30 days
- ○ Less than once a week
- ○ About once a week
- ○ 2 or 3 times a week
- ○ Daily or almost daily

55. In the last 30 days, in what ways did you bully other students? *(Mark all that apply)*

- ○ I did not bully other students in the last 30 days
- ○ Physical attacks (e.g., beat up, pushed, or kicked them)
- ○ Verbal attacks (e.g., teased, threatened, or spread rumours about them)
- ○ Cyber-attacks (e.g., sent mean text messages or spread rumours about them on the internet)
- ○ Stole from them or damaged their things

56. In the last 30 days, how often have you taken part in bullying other students?

- ○ I did not bully other students in the last 30 days
- ○ Less than once a week
- ○ About once a week
- ○ 2 or 3 times a week
- ○ Daily or almost daily

57. How supportive is your school of the following?

	Very supportive	Supportive	Unsupportive	Very unsupportive
a) Making sure there are opportunities for students to be physically active	○	○	○	○
b) Making sure students have access to healthy foods and drinks	○	○	○	○
c) Making sure no one is bullied at school	○	○	○	○
d) Giving students the support they need to resist or quit tobacco	○	○	○	○
e) Giving students the support they need to resist or quit drugs and/or alcohol	○	○	○	○

58. What academic level was your current or most recent Math course?

- ○ Applied
- ○ Academic
- ○ Other _____

59. In your current or most recent Math course, what is your approximate overall mark?
(Think about last year if you have not taken math this year)

- ○ 90% - 100%
- ○ 80% - 89%
- ○ 70% - 79%
- ○ 60% - 69%
- ○ 55% - 59%
- ○ 50% - 54%
- ○ Less than 50%

60. In your current or most recent English course, what is your approximate overall mark?
(Think about last year if you have not taken English this year)

- ○ 90% - 100%
- ○ 80% - 89%
- ○ 70% - 79%
- ○ 60% - 69%
- ○ 55% - 59%
- ○ 50% - 54%
- ○ Less than 50%

61. What is the highest level of education you would like to get? *(Choose only one)*

- ○ Some high school or less
- ○ High school diploma or graduation equivalency
- ○ College/trade/vocational certificate
- ○ University Bachelor's degree
- ○ University Master's / PhD / law school / medical school / teachers' college degree
- ○ I don't know

62. What is the highest level of education you think you will get? *(Choose only one)*

- ○ Some high school or less
- ○ High school diploma or graduation equivalency
- ○ College/trade/vocational certificate
- ○ University Bachelor's degree
- ○ University Master's / PhD / law school / medical school / teachers' college degree
- ○ I don't know

63. In the last 4 weeks, how many days of school did you miss because of your health?

- ○ 0 days
- ○ 1 or 2 days
- ○ 3 to 5 days
- ○ 6 to 10 days
- ○ 11 or more days

64. In the last 4 weeks, how many classes did you skip when you were not supposed to?

- ○ 0 classes
- ○ 1 or 2 classes
- ○ 3 to 5 classes
- ○ 6 to 10 classes
- ○ 11 to 20 classes
- ○ More than 20 classes

65. How often do you go to class without your homework complete?

- ○ Never
- ○ Seldom
- ○ Often
- ○ Usually

○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

Appendix D: School Policies and Practices Questionnaire

School Policies and Practices Questionnaire

General School Health Questions

1. **Does your school have written policies on the following?**

		Yes, a copy will be provided to COMPASS staff	No
a.	Healthy Eating	○	○
b.	Physical Activity	○	○
c.	Tobacco Use	○	○
d.	Alcohol & Drug Use	○	○
e.	Bullying	○	○

2. **What resources are available annually from your school board to support efforts to improve the health of students at your school?**

   a. Budget
      - ○ Annual budget greater than $1000
      - ○ Annual budget $500-$999
      - ○ Annual budget $100-$499
      - ○ Annual budget less than $100
      - ○ We receive no funding from the board for this

   b. Staff time (e.g., for professional development, monitoring of policy compliance, etc.)
      - ○ Yes
      - ○ No

   c. Space
      - ○ Yes
      - ○ No

3. **Has your school used data from a student health assessment at least once in the past two years to help in planning actions that will improve your school's environment and/or to help determine the impact of changes that you have made on student attitudes and behaviours?**

(Examples of student assessments are: SHAPES student survey, Youth Smoking Survey, Ontario Student Drug Use and Health Survey [OSDUHS].)

- ○ Yes
- ○ No

4. **Has your school made any health policy or health program changes <u>in the past year</u> (e.g., introducing a ban on beverages containing sugar in school vending machines)?**

   - o Yes
   - o No

5. **During the past 12 months, what role did your local <u>Public Health Unit</u> play when working with your school on health promotion and/or activities for students?** *(Check all that apply)*

   - o No contact with local Public Health Unit regarding health promotion and/or activities
   - o Provided information/resources/programs (e.g., posters, toolkits)
   - o Solved problems jointly
   - o Developed/implemented program activities jointly

6. **In which fields does your school receive support from your school's local <u>Public Health Unit</u>?** *(Check all that apply)*

   - o We do not receive any resources from Public Health
   - o Healthy eating
   - o Physical activity
   - o Tobacco use
   - o Alcohol and drug use
   - o Sedentary behaviour
   - o Obesity
   - o Bullying

7. **During the past 12 months, has your school worked with any of the following to promote health and/or health activities?** *(Check all that apply)*

   - o Health organization (e.g., Canadian Cancer Society, Heart and Stroke Foundation, Canadian Diabetes Association)
   - o Parks or Recreation department
   - o Youth organization (e.g., YMCA/YWCA, Boys/Girls Clubs, Boy Scouts/Girl Guides)
   - o Health or fitness club
   - o Board/division/district itinerant teacher (e.g., consultant, specialist)

8. **Please rank these school/health-related issues in terms of importance to your school (1=highest priority, 2=second highest priority, etc.):**

a.	Tobacco Use	_____
b.	Alcohol and other Drug Use	_____
c.	Healthy Eating	_____
d.	Physical Activity	_____
e.	Bullying/Violence	_____
f.	Mental Health	_____
g.	Sexual Health	_____
h.	Sun safety/tanning beds	_____
i.	Obesity	_____
j.	Sedentary behaviours / screen-time	_____

9. **Are there any other school/health-related issues that are important to your school that are not listed in Question 8 above?**

   - ○ Yes → Please list:
     _____
   - ○ No

10. **Are your school's <u>written health policies</u> (e.g., smoking rules, healthy eating requirements, drug policies) communicated to <u>students</u>?**

    - ○ Yes → Please indicate how they are communicated:
      _____
    - ○ No

Physical Activity Questions

11. **Is the physical inactivity of students a problem at your school?**
    - ○ Yes
    - ○ No
    - ○ I don't know

12. **Do the majority of students at your school have regular access to <u>INDOOR</u> physical activity areas during <u>non-instructional school time?</u>** *(e.g., during lunch, spare periods)*

    - ○ Yes on school grounds only
    - ○ Yes, off school grounds only
    - ○ Yes, both on and off school grounds
    - ○ No
    - ○ I don't know

13. **Do the majority of students at your school have regular access to <u>OUTDOOR</u> physical activity areas during <u>non-instructional time?</u>** *(e.g., during lunch, spare periods)*

    - ○ Yes on school grounds only
    - ○ Yes, off school grounds only
    - ○ Yes, both on and off school grounds
    - ○ No
    - ○ I don't know

14. **Does your school have:**

		Yes	No
a.	Gymnasium(s)	○	○
b.	Indoor facilities (e.g., dance studio, yoga room, fitness room)	○	○
c.	Outdoor facilities (e.g., playing fields, paved activity areas, baseball diamond)	○	○

15. Do students have access to physical activity equipment such as soccer and basketballs during <u>non-instructional times</u> throughout the school day? *(e.g., during lunch, or spare periods)*

- o Always
- o Sometimes
- o Never

16. Do the majority of students at your school have <u>regular access</u> to any of the following*?*

			Yes	No
a.	Secure change room lockers available for use during physical activity		○	○
b.	Change rooms available for use before and after physical activity		○	○
c.	**<u>If yes</u>**, are privacy curtains/stalls (**<u>not</u>** including shower or bathroom stalls) available for ...	i. Girls?	○	○
		ii. Boys?	○	○
d.	Clean showers available for use before and after physical activity	i. Girls?	○	○
		ii. Boys?	○	○

17. <u>Outside of school hours</u>, does your school permit <u>regular student access</u> to the following?
(Outside of school hours means before school, after school, evenings, and weekends. Student access may occur via school-led, community-led, or informal use.)

		Yes	No	N/A
a.	Gymnasium(s)	○	○	○
b.	Indoor facilities (e.g., dance studio, yoga room, fitness room)	○	○	○
c.	Outdoor facilities (e.g., playing fields, paved activity areas, baseball diamond)	○	○	○
d.	Equipment (e.g., soccer balls, basketballs)	○	○	○

18. Does your school offer <u>intramural programs/club activities</u> that involve physical activity?
(Intramural programs/club activities are school-sponsored physical/recreational activities that occur outside of instructional time, are available to all students, are focused on maximizing participation, and are limited to individuals/groups/teams of the school population.)

- o Yes
- o No

19. During the <u>past 12 months</u>, how many <u>intramural programs</u> that involve physical activity were available to students over the course of the school year?

- o Fall_____
- o Winter_____
- o Spring_____

20. Does your school offer <u>non-competitive sports clubs</u> *(e.g. rock climbing, dance, outdoor club)* that involve physical activity?

- o Yes

- No

21. Does your school offer <u>interschool or varsity programs</u> that involve physical activity?
(Interschool programs are board/ school-sponsored competitive athletic programs that occur outside of instructional time, are available to select individuals/groups, and are competitive against other schools.)

- Yes
- No

22. During the <u>past 12 months</u>, how many <u>interschool or varsity programs</u> that involve physical activity were available to students over the course of the school year?

- Fall_____
- Winter_____
- Spring_____

23. How many hours of Physical Education are <u>mandatory</u> for each grade at your school in a school year?

a. Grade 9 _____
b. Grade 10 _____
c. Grade 11 _____
d. Grade 12 _____

24. Does your school promote physical activity during or as part of special events (e.g., Terry Fox Run, Jump Rope for Heart)?

- Yes →Please list events:
  _____
- No

Healthy Eating Questions

25. Is unhealthy eating among students a problem at your school?

- Yes
- No
- I don't know

26. Who operates the following food services in your school? *(Check all that apply)*

		School	School council (i.e. parent council)	Food service company	Non-profit organization	Students	Other	We do not have one
a.	Cafeteria	○	○	○	○	○	○	○
b.	Snack bar/Tuck shop	○	○	○	○	○	○	○
c.	Vending	○	○	○	○	○	○	○

Machine(s)

27. Does your school have a breakfast program for students?

- ○ Yes
- ○ No *(Skip to question 31)*

28. How often is the breakfast program offered?

- ○ 1 day per week
- ○ 2 days per week
- ○ 3 days per week
- ○ 4 days per week
- ○ 5 days per week

29. Is the breakfast program free?

- ○ Yes
- ○ No → How much does it cost? _____

30. Is the breakfast program available to <u>all</u> students?

- ○ Yes
- ○ No → What is the restriction? _____

31. Does your school offer any of the following? *(Check all that apply)*

		Yes	No
a.	Cooking classes	○	○
b.	Gardening (e.g., growing produce)	○	○
c.	Field trips to farms/farmers' markets	○	○
d.	Media literacy on special topics related to healthy eating (e.g., body image, eating disorders)	○	○
e.	Field trips to the local grocery store	○	○

32. Does your school have programs in place to help students understand nutrition?

- ○ Yes → Please list:
  _____
- ○ No

33. <u>During the past 12 months</u>, have school staff received:

		For nutrition	For promoting positive body image
a.	In-service training (e.g., by Public/Regional Health)	○	○
b.	Conferences	○	○
c.	Workshops on professional development days	○	○
d.	Presentations by Community Organizations	○	○
e.	Teacher initiated self-training on the Internet at home	○	○

f.	Teacher initiated self-training on the Internet at school	○	○
g.	Faculty of Education courses	○	○
h.	Other (please specify): _____ _____ _____ _____	○	○

34. Does school staff have clear guidelines to refer students with suspected eating disorders to the appropriate health professional or community agency?

- ○ Yes
- ○ No
- ○ I don't know

Bullying Questions

35. Is bullying a problem at your school?

- ○ Yes
- ○ No
- ○ I don't know

36. Does your school have any programs that address bullying?

- ○ Yes → Please list:
  _____
- ○ No

Substance Use Questions

37. Are any of the following substance use behaviours a problem among students at your school?

		Yes	No	I don't know
a.	Tobacco use	○	○	○
b.	Alcohol use	○	○	○
c.	Drug use	○	○	○

38. Does your school <u>prohibit</u> students smoking tobacco (e.g. cigarettes, cigars, cigarillos) in each of the following locations? *(Check all that apply)*

		Yes	No
a.	Within a specified distance of school grounds	○	○
b.	Private vehicles parked on school grounds	○	○
c.	Sponsored events <u>off</u> of school grounds	○	○

39. Does your school <u>prohibit</u> student use of <u>smokeless tobacco</u> (e.g. chewing tobacco, pinch, snuff, or snus) in each of the following locations?

		Yes	No
a.	In class	○	○
b.	Anywhere on school property during school hours	○	○
c.	During school activities off school property (e.g. field trips, school sport events)	○	○

40. Does your school have a designated spot on school grounds where students are allowed to smoke?

- ○ Yes
- ○ No
- ○ No, but there is an area off of school grounds within view of the school

41. What are the consequences for a <u>first offense</u> for students who are caught violating your school's written policies or practices on the following? *(Check all that apply)*

		Tobacco	Alcohol	Drugs
a.	Issue warning (written or verbal)	○	○	○
b.	Inform parents or guardians	○	○	○
c.	Refer to a school administrator	○	○	○
d.	Refer to a school counsellor	○	○	○
e.	*Encourage*, but not require, to participate in an assistance, education, or cessation program	○	○	○
f.	*Require* to participate in an assistance, education or cessation program	○	○	○
g.	Confiscate substance	○	○	○
h.	Assign additional class work (written/presentation)	○	○	○
i.	Assign to help around school	○	○	○
j.	Fine	○	○	○
k.	Place in detention	○	○	○
l.	Give in-school suspension	○	○	○
m.	Suspend from school	○	○	○
n.	Alert police		○	○

42. Do sanctions get stronger with subsequent violations (i.e., progressive discipline approach)?

		Tobacco	Alcohol	Drugs
a.	Always	○	○	○
b.	Sometimes	○	○	○
c.	Never	○	○	○

43. How consistently are your school's written policies (e.g., smoking/drinking/using drugs on school property) <u>ADHERED to by students</u>?

		Tobacco	Alcohol	Drugs
a.	Always	○	○	○
b.	Most of the time	○	○	○
c.	Sometimes	○	○	○
d.	Rarely	○	○	○

e.	Never	○	○	○

44. Does your school provide any <u>tobacco prevention</u> programs?

- ○ Yes→ Please list:

  _____

- ○ No

45. Does your school provide any <u>tobacco cessation</u> programs?

- ○ Yes→ Please list:

  _____

- ○ No

46. Does your school provide any <u>alcohol use prevention</u> programs?

- ○ Yes→ Please list:

  _____

- ○ No

47. Does your school provide any <u>marijuana/drug use prevention</u> programs?

- ○ Yes→ Please list:

  _____

- ○ No

48. Are students at your school allowed to carry or wear apparel or paraphernalia with company names or logos on them for any of the following?

	Yes	No	I don't know
Tobacco	○	○	○
Alcohol	○	○	○
Marijuana/ other drugs	○	○	○

49. Which of the following methods have been used to provide teachers with prevention and/or cessation education <u>during the last school year</u>? *(Check all that apply)*

		Tobacco	Alcohol	Drugs
a.	In-service training (e.g., by Public/Regional Health)	○	○	○
b.	Conferences	○	○	○
c.	Workshops on professional development days	○	○	○
d.	Presentations by organizations	○	○	○
e.	Teacher initiated self-training on the Internet at home	○	○	○
f.	Teacher initiated self-training on the Internet at school	○	○	○
g.	Faculty of Education courses	○	○	○

h.	Other (please specify): _____ _____ _____ _____	○	○	○

School Policies and Practices Year 2

Please provide as much detail as possible in this chart. We have provided a summary of what was reported in the School Policy and Practices Questionnaire and follow-up interview completed at your school last year. This information will aid the COMPASS team with investigating the impact of your school's changes in policies, practices or environmental factors on student health related behaviour.

Behaviour	**2012-13 Summaries**	**Have any changes been made since last school year?** *Please provide details on a) whether past policies, practices, environment and relationships are still in place, and b) whether any new policies, practices, environment changes or relationships are planned or being implemented*	
Healthy Eating	***Is unhealthy eating among students a problem at your school?*** - Yes	Is unhealthy eating among students a problem at your school this year? ☐ Yes ☐ No	
	Policies: - Implemented the mandatory PPM150	Policy Changes ☐ Yes ☐ No	If yes, please provide details
	Practices: - Free snack program is offered 5 days week for all students - School offers cooking classes, media literacy on special topics related to healthy eating, field trips to local grocery store - School does not provide gardening or field trips to farms/farmers market	Practices Changes ☐ Yes ☐ No	If yes, please provide details
	Environment/Equipment: - No food services (i.e. cafeteria, snack bar, vending machines) on	Environment or equipment Changes ☐ Yes	If yes, please provide details

	school property. - Nutrition is taught in PE	☐ No	
	Public Health: - Provided presentations to staff, provided personal support for menu planning and information for parents - Northwestern Health Unit survey information and school surveys through PE and social science classes and Safe and Healthy Lifestyles committee	Changes with relationships with Public Health: ☐ Yes ☐ No	If yes, please provide details
Behaviour	**2012-13 Summaries**	**Have any changes been made since last school year?** *Please provide details on a) whether past policies, practices, environment and relationships are still in place, and b) whether any new policies, practices, environment changes or relationships are planned or being implemented*	
Physical Activity	***Is physical inactivity among students a problem at your school?***	*Is physical inactivity among students a problem at your school* your school this year? ☐ Yes ☐ No	
	Policies:	Policy Changes ☐ Yes ☐ No	Please provide details on a) whether past policies are still in place, and b) whether new policies are planned or being implemented
	Practices:	Practices Changes ☐ Yes ☐ No	If yes, please provide details
	Environments & Equipment:	Environment or	If yes, please provide details

		equipment Changes ☐ Yes ☐ No	
	Public Health:	Changes with relationships with Public Health: ☐ Yes ☐ No	If yes, please provide details

2012-13 Response	2013-14 Response
Please rank these school/health-related issues in terms of importance to your school from 1 to 10 (1= highest priority…10=lowest priority.): a. Tobacco Use 8 b. Alcohol and other Drug Use 4 c. Healthy Eating 5 d. Physical Activity 6 e. Bullying/Violence 2 f. Mental Health 1 g. Sexual Health 3 h. Sun safety/tanning beds 10 i. Obesity/overweight/healthy weight 7 j. Sedentary behaviours/screen-time 9	**Please rank these school/health-related issues in terms of importance to your school from 1 to 10 (1= highest priority…10=lowest priority.):** a. Tobacco Use _____ b. Alcohol and other Drug Use _____ c. Healthy Eating _____ d. Physical Activity _____ e. Bullying/Violence _____ f. Mental Health _____ g. Sexual Health _____ h. Sun safety/tanning beds _____ i. Obesity/overweight/healthy weight _____ j. Sedentary behaviours/screen-time _____ ☐ **Same priority ranking as last year** **If physical activity and healthy eating are top priorities is it because obesity, overweight and/or healthy weight are problems at your school?**

	☐ Yes ☐ No

Please select the <u>interschool or varsity</u> programs involving physical activity that are/will be offered to students at your school during this school year.

Sport/Game	Junior Girl's	Senior Girl's	Junior Boy's	Senior Boy's
Soccer	○	○	○	○
Cross country running	○	○	○	○
Tennis	○	○	○	○
Basketball	○	○	○	○
Football	○	○	○	○
Field hockey	○	○	○	○
Ice Hockey	○	○	○	○
Volleyball	○	○	○	○
Wrestling	○	○	○	○
Swimming	○	○	○	○
Curling	○	○	○	○
Alpine Skiing	○	○	○	○
Cross-Country Skiing	○	○	○	○
Badminton	○	○	○	○
Rugby	○	○	○	○
Rowing	○	○	○	○
Baseball/softball	○	○	○	○

Track and field	○	○	○	○
Other:_____	○	○	○	○
Other:_____	○	○	○	○
Other:_____	○	○	○	○

Was this different last year? Have new teams been added or dropped since last year?

- ☐ Yes, please explain:_____
- ☐ No

Appendix E:

Manuscript 1 Supplementary Material

This appendix includes supplementary material from the first manuscript in this dissertation: *Clustering of risk-related modifiable behaviours and their association with overweight and obesity among a large sample of youth in the COMPASS study.*

Table 12 provides the breakdown of the item response probabilities for all of the factors included in the latent class analysis. The proportion of youth in each behavioural cluster that self-reported being overweight or obese is presented in Figure 13. Finally, Table 13 provides a detailed description of the four behavioural clusters identified through the latent class analysis.

Table 12. Item response probabilities from the latent class analysis for students participating in Year 1 of the COMPASS Study (2012-2013) (n=18,587)

	Group name	*Traditional School Athlete*	*Inactive Screenagers*	*Health Conscious*	*Moderately Active Substance Users*
		Class membership probabilities			
		0.24	0.41	0.18	0.17
	Group description	1. active 2. poor eating 3. no substance use behaviours	1. inactive 2. high screen time 3. poor eating - no substance use	All healthy – low fruit and vegetable consumption like all other groups	1. meeting PA guidelines, all other health behaviours poor – highest probability of sugar sweetened beverage consumption, still below 0.5
Items/health behaviours and their response probabilities (rho estimates)	Low physical activity	0.38	**0.62**	0.49	0.43
	Low strength training	**0.50**	**0.73**	0.45	**0.56**
	No varsity sports	0.04	**0.90**	0.33	**0.61**
	No intramurals	0.14	**0.89**	0.41	**0.72**
	High internet use	0.47	**0.58**	0.23	**0.57**
	High video games	0.31	0.35	0.11	0.35
	High TV use	**0.58**	**0.59**	0.28	**0.57**
	Low fruit/vegetable consumption	**0.70**	**0.85**	**0.54**	**0.77**
	Low breakfast consumption	**0.53**	**0.57**	0.25	**0.73**
	High fast food	**0.79**	**0.68**	0.35	**0.85**
	High corner store	0.48	0.32	0.11	**0.52**
	High sugar-sweetened beverage consumption	0.45	0.35	**0.10**	0.47
	Smoker (any type other than smokeless)	0.07	0.02	0.02	**0.64**
	Marijuana use	0.11	0.07	0.03	**0.76**

	Binge drinker	0.24	0.10	0.12	**0.78**

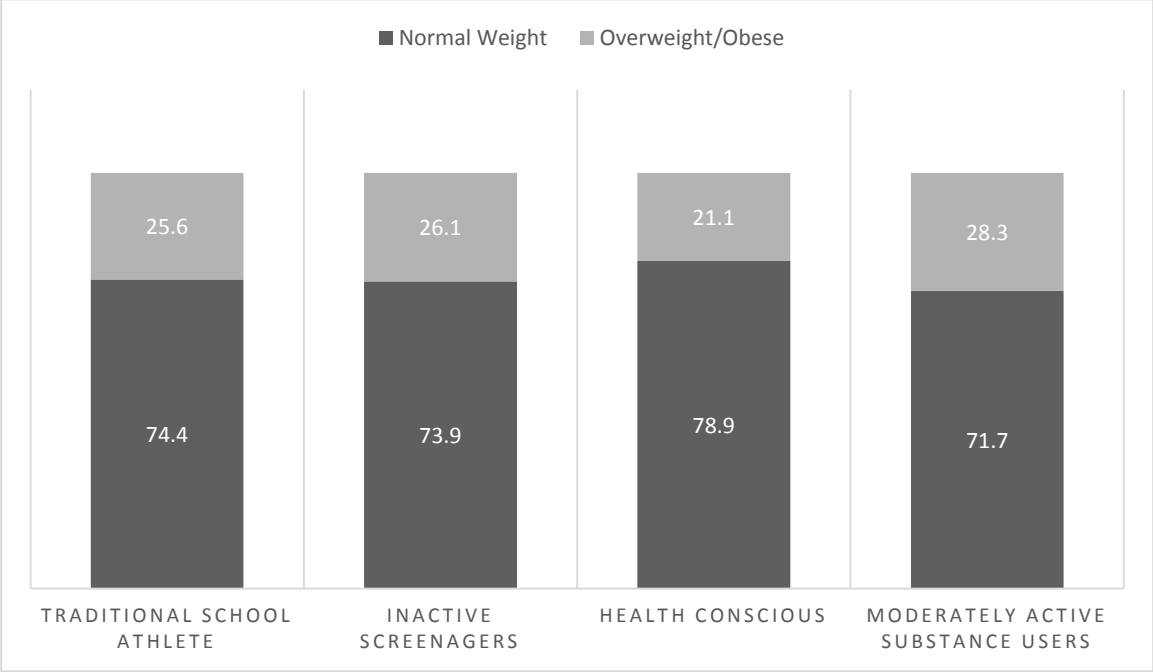


Figure 13. Proportion of overweight/obese students belonging to each behavioural cluster, among students participating in Year 1 of the COMPASS Study (2012-2013) (n=18,587)

Table 13. Detailed description of the latent classes identified from year 1 of the COMPASS Study (n=18,587) (2012-2013)

Latent Class	**Description**
Traditional school athletes	More than half of the youth in this subgroup were meeting physical activity recommendations (63.6%), and engaging in strength training (50.5%). Almost all were a part of varsity teams (99.1%) or played intramural sports (87.4%). Less than half were meeting screen time recommendations (46.9% surfing internet and 59.2% watching television for more than two hours per day), but this subgroup was spending less time surfing the internet than groups 2 and 4. More than two-thirds of youth in this subgroup (70.3%) were not consuming at least 5 servings of fruits and vegetables per day, half were not consuming breakfast daily (52.3%), 81.5% were eating at fast food restaurants one or more times per week, and 45.9% consume sugar-sweetened beverages at least three times per week. A very small proportion of youth in this subgroup smoked (cigarettes or alternative tobacco products), but approximately 10% use marijuana while 25.7% were considered binge drinkers, unsurprising given that youth making up this subgroup were more likely athletes (i.e., jocks), which is associated with binge drinking and some marijuana use.
Inactive screenagers	Only 37% of youth in this subgroup were meeting physical activity recommendations, and even less were participating in strength training at least three times per week (26.1%). Of the 45.7% of youth in the total sample that participate in varsity sports, only 7.6% of them were in this subgroup. This is similar for intramurals, with only 11.2% of youth in this subgroup participating in intramural

	sports (only 638 students in this whole group were participating in intramural sports). In this group, more than half (58%) of youth spend more than two hours per day surfing the internet and watching television. The large majority of youth in this subgroup were not consuming at least five servings of fruits and vegetables daily (85%), and more than half (57%) skip breakfast and consume fast food more than once per week (67.7%).
Health conscious	Youth in this subgroup were considered to be the healthiest, with item response probabilities suggesting physical activity, low screen time, healthier eating habits, and no substance use. In fact, more than half of the youth in this subgroup were meeting physical activity guidelines (54.6%), engaged in strength training at least three times per week (59.1%), and participated in varsity (73.0%) and intramural (61.8%). The majority of youth in this subgroup met the recommendations for sedentary behaviour – 81.8% spent less than 2 hours per day surfing the internet, 8.5% spent less than 2 hours playing video games, and 23.6% spent less than 2 hours watching television per day. While no subgroup showed optimal fruit and vegetable consumption, this subgroup had the highest proportion of youth meeting recommendations, with 51.3% eating at least 5 servings of fruits or vegetables per day. Most youth in this subsample report eating breakfast everyday (79.5%), not eating at fast food restaurants (71.6%) or at corner stores (93.6%), and not drinking sugar sweetened beverages (93.7%), Finally, less than 3% of youth in this sample reported smoking or using marijuana, while 88.7% reported not binge drinking.
Moderately Active substance users	Youth in this group were more active than subgroup 2, but had high response probabilities for the majority of poor health behaviours. More than half of youth in this subgroup spent two or more hours per day surfing the internet (57%) and watching television (56.3%). Three quarters were not consuming breakfast (74.9%) or five or more servings of fruits and vegetables per day (76.9%). 85% of youth in this subgroup were consuming fast food one or more time per week. Most notably, the majority of youth in this group were engaging in risky health behaviours, including smoking (69.8%), marijuana use (82.6%), and binge drinking (79.4%).

I also assessed the correlation of the variables that were entered into the latent class analysis. However, correlation does not matter as much in this method as it does in factor analysis – factor analysis is concerned with the structure of variables (correlations), while LCA is more concerned with the structures of cases (latent taxonomic structure). LCA is more closely related to cluster analysis – used to discover groups or types of cases based on observed data, and using this, to assign cases to groups. I determined that the food variables were not highly correlated; the highest correlation was between corner store snack purchases and fast food (0.23).

- marijuana use and smoking had a correlation of 0.43
- binge and marijuana had a correlation of 0.40
- smoking and binge drinking had a correlation of 0.39

Table 14 shows the distribution of health behaviours across students that belong to the different latent classes, as identified by their data.

Table 14. Distribution of health behaviours across the latent classes in Year 1 (2012-13) of the COMPASS Study in Ontario, Canada

	Latent Classes			
	Traditional School Athlete	*Inactive Screenagers*	*Health Conscious*	*Moderately Active Substance Users*
Sex				
Male	61.8	43.3	44.4	62.4
Female	38.2	56.7	55.6	37.6
Physical activity				
Physical activity				
≥ 60 minutes/day	63.6	37.0	54.7	56.4
< 60 minutes/day	36.4	63.0	45.3	43.6
Missing (#)	352			
Strength training				
≥ 3 days per week	50.5	26.1	59.1	43.9
< 3 days per week	49.6	74.0	41.0	56.1
Missing	153			
Participates in school intramurals				
Yes	87.4	11.2	61.8	28.9
No	12.6	88.8	38.2	71.1
Missing (#)	141			
Participates in varsity sports				
Yes	99.1	8.0	73.0	39.9
No	0.10	92.0	27.0	60.1
Missing (#)	136			
Dietary behaviours				
Breakfast consumption				
I eat breakfast everyday	47.8	43.1	79.5	25.2
I do not eat breakfast everyday	52.3	56.9	20.5	74.9
Missing	241			
Fruit and vegetable consumption				
≥ 5 servings/day	29.7	14.1	51.3	23.1
< 5 servings/day	70.3	85.2	48.7	76.9
Missing	338			
Fast food consumption				
Never	18.5	32.4	71.6	14.9
≥ 1 time per week	81.5	67.7	28.4	85.1
Missing	443			
Snacks purchased off of school property				
Never	50.6	68.4	93.6	47.6

≥ 1 time per week	49.4	31.6	6.4	52.4
Missing (#)	508			
Sugar sweetened beverage consumption				
≤ 3 days per week	54.1	65.3	93.7	53.1
≥ 4 days per week	45.9	34.8	6.3	46.9
Missing	482			
Sedentary behaviour				
Internet Surfing				
< 2 hours/day	53.1	41.9	81.8	43.1
≥ 2 hours/day	46.9	58.1	18.2	57.0
Missing (#)	16			
Video Games				
< 2 hours/day	68.9	65.1	91.5	64.5
≥ 2 hours/day	31.1	35.0	8.5	35.5
Missing (#)	16			
Television				
< 2 hours/day	40.9	41.3	76.4	43.7
≥ 2 hours/day	59.2	58.7	23.6	56.3
Missing (#)	16			
Other Risky Behaviours				
Current tobacco user				
No	94.3	98.3	98.7	30.2
Yes	5.7	1.7	1.3	69.8
Current binge drinker				
No	74.3	90.7	88.7	20.6
Yes	25.7	9.3	11.3	79.4
Missing	63			
Current marijuana user				
No	90.5	93.2	97.4	17.4
Yes	9.5	6.8	2.6	82.6
All values presented as % within subgroup				

This study suggests a potential normative shift in diet, activity, and screen time behaviours. Gender differences were also noted across the classes, with a higher number of females belonging to the "health conscious" cluster, and a larger proportion of males belonging to both the "typical school athlete" and "moderately-active substance user" clusters.

Figure 14 displays the proportion of COMPASS students meeting 0, 1, 2, or 3 of behavioural recommendations/guidelines of (1) >60 minutes of physical activity daily, (2) 7-8 servings of fruits and vegetables, and (3) < 2 hours of screen time per day.

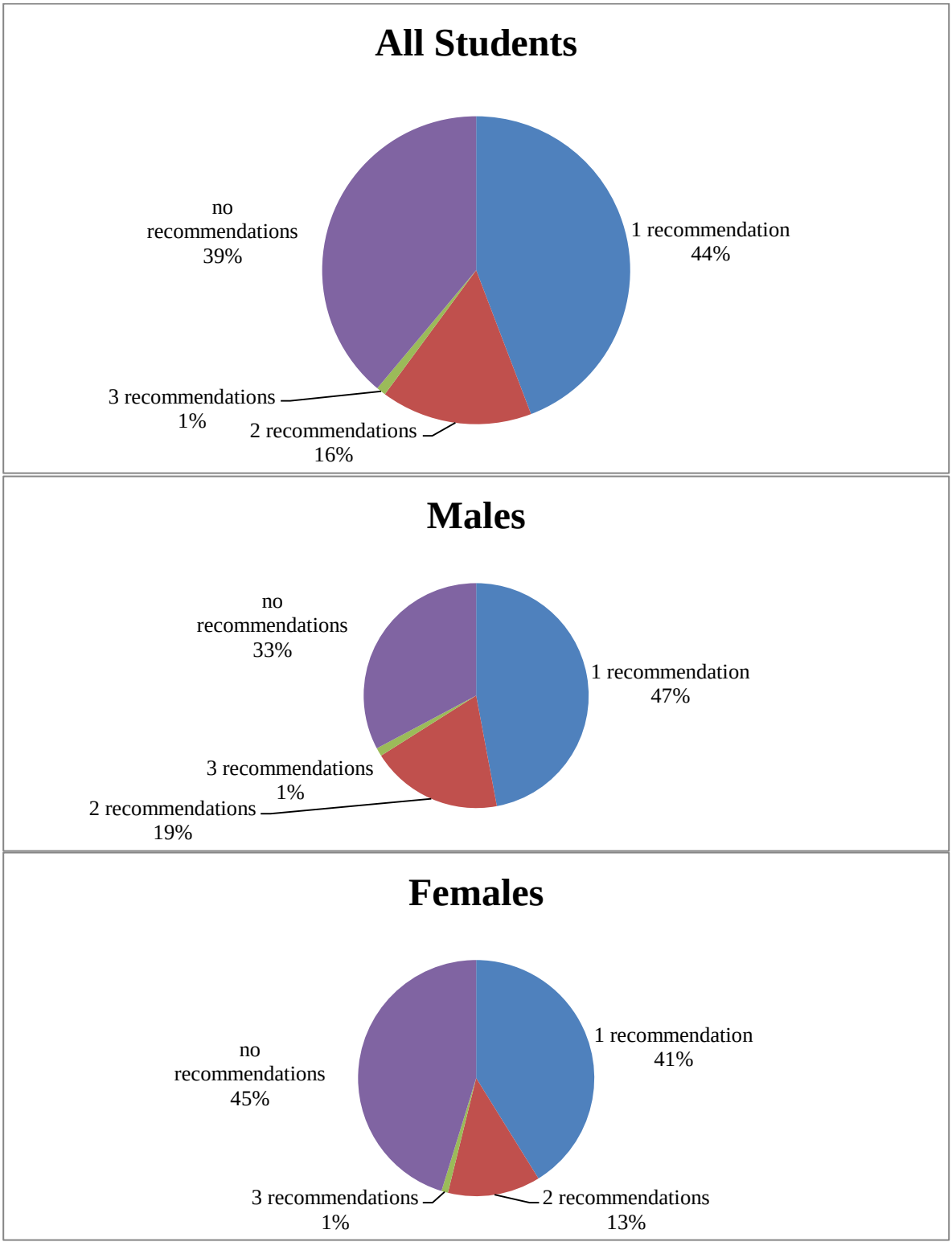


Figure 14. Proportion of students in Y1 of COMPASS meeting behavioural recommendations

Finally, given the differences in behaviours between male and female students, I also performed stratified LCA models by gender, results of which can be seen in Table 15 (females) and Table 16 (males). You will note that the latent classes that came out of the data were not entirely aligned with the overall model. In the LCA for females, their class 3 was not as *Health conscious* as the overall cluster or that of the male students, as they did not appear to have the same level of activity as the male students. The female students more likely to be active were those that belonged to class 1, similar to the overall *Traditional School Athlete* cluster. Cluster 3 in females did embody, however, the other characteristics that would classify them as *Health Conscious*, with lower screen time, better dietary behaviours, and low probability of substance use. On the other hand, the male students in cluster 3 were representative of the *Health Conscious* cluster identified in the latent class analysis with the overall sample. Cluster 2 for both the female and male students was similar to that of the overall sample, with low physical activity and high screen time. You will note that the females in this cluster had a much lower probability of engaging in high video game use, but this probability was still the highest among the four clusters (0.24 as compared to 0.07, 0.006, and 0.18). Cluster 4 in both females and males were the most likely to be using substances, especially marijuana and binge drinking. Females were less likely to be smoking than males (0.49 compared to 0.73), but again, the probability of smoking in this cluster was higher than in any of the other clusters.

Table 15. Item response probabilities from the LCA stratified by gender from Year 1 of the COMPASS Study (2012-2013) (n=9,089) (females only)

		1	2	3	4
		Class membership probabilities			
		0.27	0.27	0.31	0.15
Items/health behaviours and their response probabilities (rho estimates)	Low physical activity	0.48	**0.61**	**0.69**	**0.53**
	Low strength training	**0.53**	**0.78**	**0.68**	**0.65**
	No varsity sports	0.05	**0.86**	**0.85**	**0.69**
	No intramurals	0.11	**0.83**	**0.84**	**0.73**
	High internet use	0.42	**0.74**	0.41	**0.64**
	High video games	0.07	0.24	0.006	0.18
	High TV use	0.44	**0.73**	0.42	**0.57**
	Low fruit/vegetable consumption	**0.65**	**0.89**	**0.74**	**0.81**
	Low breakfast consumption	0.47	**0.74**	0.40	**0.78**
	High fast food	**0.59**	**0.81**	0.46	**0.81**
	High corner store	0.30	0.46	0.12	0.47
	High sugar-sweetened beverage consumption	0.22	0.43	0.11	0.38
	Smoker (any type other	0.02	0.03	0.01	0.49

	than smokeless)				
	Marijuana use	0.06	0.06	0.04	**0.74**
	Binge drinker	0.18	0.12	0.09	**0.79**

Table 16. Item response probabilities from the LCA stratified by gender from Year 1 of the COMPASS Study (2012-2013) (n=9,498) (males only)

		1	2	3	4
		Class membership probabilities			
		0.27	0.36	0.16	0.21
Items/health behaviours and their response probabilities (rho estimates)	Low physical activity	0.34	**0.55**	0.36	0.37
	Low strength training	0.49	**0.69**	0.33	**0.50**
	No varsity sports	0.03	**0.88**	0.26	**0.52**
	No intramurals	0.16	**0.89**	0.39	**0.67**
	High internet use	0.44	**0.54**	0.15	**0.51**
	High video games	0.43	**0.62**	0.20	0.43
	High TV use	**0.59**	**0.56**	0.30	**0.56**
	Low fruit/vegetable consumption	**0.69**	**0.84**	**0.50**	**0.74**
	Low breakfast consumption	0.49	**0.51**	0.19	**0.70**
	High fast food	**0.81**	**0.69**	0.37	**0.88**
	High corner store	**0.50**	0.34	0.13	**0.55**
	High sugar-sweetened beverage consumption	**0.50**	0.44	0.17	**0.51**
	Smoker (any type other than smokeless)	0.07	0.03	0.04	**0.73**
	Marijuana use	0.10	0.09	0.06	**0.76**
	Binge drinker	0.23	0.08	0.15	**0.76**

Appendix F:
Manuscript 2 Supplementary material

This appendix includes supplementary material from the second manuscript in this dissertation: *Behavioural patterns only predict concurrent BMI status and not BMI trajectories in a sample of youth in Ontario, Canada.*

I identified the variation in BMI explained by the school: Correlation: 0.0177, $p<0.0001$ – suggesting that 1.8% of the variation in BMI is explained by the school level, and must be controlled for in the analyses.

With the help of Ashok (co-author), I created box plots to explore the differences in average BMI across the four behavioural clusters over the three waves of COMPASS (Figure 15). As mentioned in the limitations section of manuscript 2 (page 81), the average BMI across the clusters overlapped, suggesting there may not have been sufficient differences between the groups.

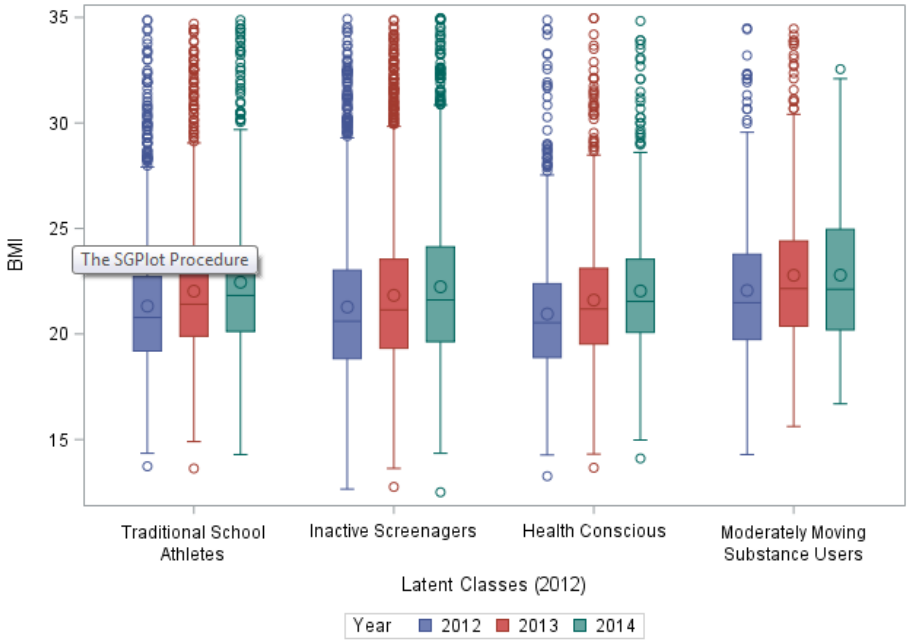


Figure 15. Box plots showing average BMI across behavioural clusters

Figure 16 is a display of the results from the final model in manuscript 2 with the inclusion of an interaction term by time (latent cluster * time). The behavioural cluster by time interaction term was not statistically significant across all clusters. However, results might suggest some practical importance; while the rate of BMI change among the different cluster groups was not significantly

different, the *Inactive Screenagers'* increase in BMI is slower than that of the other groups. This warrants further investigation with a larger sample of students, and still suggest that interventions may be warranted for all groups, targeting the risky behaviours that might be present in all clusters

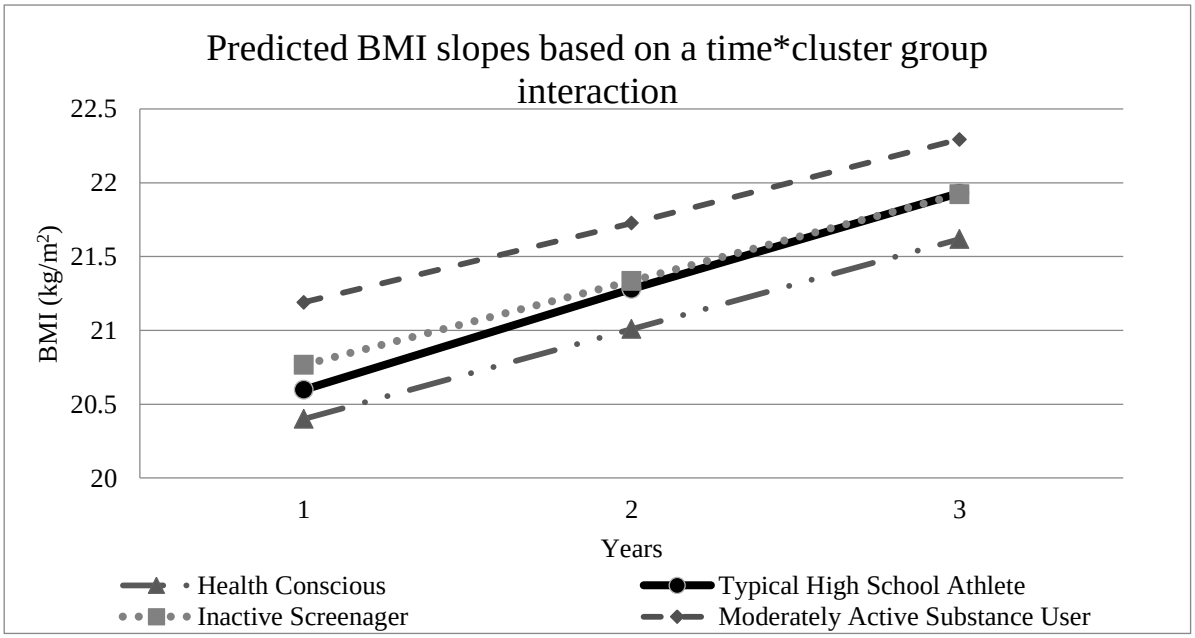


Figure 16. Model-based predicted BMI slopes for the 4 behavioural clusters from the linked longitudinal sample of youth participating in Y1 to Y3 of the COMPASS Study in Ontario, Canada (2012–2015)

Out of interest, I also modeled each individual behaviour in comparison to their healthier counterpart (all dichotomized in the latent class analysis paper). This model was intended to show which specific behaviours, when pulled out of their independent latent classes, might be most predictive of a change in BMI. This model identified that the factors predicting an increase in BMI trajectory included:

1. Not meeting physical activity guidelines (+0.194 kg/m^2)
2. Not participating in intramural sports (+0.267 kg/m^2)
3. High internet use, more than 2 hours per day (+0.198 kg/m^2)
4. High video game use, more than 2 hours per day (+0.071 kg/m^2)
5. High television viewing, more than 2 hours per day (+0.243 kg/m^2)
6. Low fruit and vegetable consumption, less than 5 FV/day (+0.120 kg/m^2)
7. Not eating breakfast daily (+0.428 kg/m^2)
8. Smoking (+0.317 kg/m^2)
9. Marijuana use (+0.188 kg/m^2)
10. Binge drinking (+0.220 kg/m^2)

And factors associated with a decrease in BMI trajectories included:

1. Not strength training (-0.096 kg/m^2)
2. Not participating in varsity sports (-0.254 kg/m^2)
3. Consuming snacks from a corner store 1/week (-0.316 kg/m^2)
4. Drinking sugar sweetened beverages (-0.160 kg/m^2)

Table 17. The effect of individual behaviours at baseline on BMI trajectories in students participating in three years of the COMPASS Study (2012/13 to 2014/15) (n=5,084)

	Modeling individual behaviours		
	B	**SE**	**P**
Year	0.540	0.0117	<.0001
Gender			
Male	1.110	0.0214	<.0001
Female	--	--	--
Grade			
9	--	--	--
10	0.370	0.0189	<.0001
11	0.595	0.0584	<.0001
12	-0.125	0.2779	0.6538
Race			
White	--	--	--
Aboriginal	0.479	0.0687	<.0001
Other	-0.037	0.0235	0.1120
Spending money			
$0	--	--	--
$1 to $20	0.047	0.0260	0.0702
$21 to $100	0.020	0.0289	0.4932
More than $100	0.082	0.0432	0.0567
I do not know	-0.188	0.0334	<.0001
Health Behaviours			
Not meeting physical activity guidelines	0.194	0.0191	<.0001
Strength training less than 3 days/week	-0.096	0.0193	<.0001
No varsity sports	-0.254	0.0219	
No intramurals	0.267	0.0217	<.0001
High internet use (>2 hours)	0.198	0.0193	<.0001
High video game use (>2 hours)	0.071	0.0226	0.0017
High television viewing (>2 hours)	0.243	0.0187	<.0001
Consuming less than 5 servings of fruits/vegetables per day	0.120	0.0210	<.0001
Non-daily breakfast consumption	0.428	0.0190	<.0001
Fast food consumption at least once per week	-0.039	0.0203	0.0570
Snacks consumed from a corner store at least once per week	-0.316	0.0205	<.0001
Sugar-sweetened beverage consumption three or more times per week	-0.160	0.0201	<.0001
Current smoker	0.317	0.0441	<.0001
Current marijuana user	0.188	0.0372	<.0001
Current binge drinker	0.220	0.0315	<.0001

Appendix G:

Manuscript 3 supplementary material

This appendix includes supplementary material from the third manuscript in this dissertation: *Non-comprehensive and intermittent obesity-related school programming and policies may not work: evidence from the COMPASS Study*.

Specific questions from the School Policies and Practices Questionnaire used to examine the school-level factors that might influence student BMI (Table 18):

Table 18. Questions from the School Policies and Practices Questionnaire (baseline and changes) used to classify the school environment

General questions Does your school have written policies on the following: - Healthy eating - Physical activity During the past 12 months, has your school worked with any of the following to promote health and/or health activities? - Health or fitness club
Physical Activity Does your school offer intramural programs/club activities that involve physical activity? Does your school offer non-competitive sports club? Does your school offer interschool or varsity programs that involve physical activity? Does your school promote physical activity during or as part of special events?
Healthy Eating Does your school have a breakfast program for students? Does your school offer any of the following? - Cooking classes - Gardening - Field trips to farms/farmers' markets - Media literacy on special topics related to healthy eating - Field trips to local grocery stores Does your school have programs in place to help students understand nutrition?
Changes from year 1 to year 2: schools were provided with their responses to their 2012-2013 SPP and were asked to indicate if (and what) changes were made between 2012-2013 and 2013-2014. - Have any changes been made since last school year related to : o Policy changes o Practices/program changes

Table 19. Summary statistics for baseline demographic variables. Mean is reported for continuous variables and percentage is reported for categorical variables (N=4951)

Variable	Summary statistics
Gender, %	
Male	47.6%
Female	52.5%
Grade, %	
9	47.7%

10	52.3%
Race/ethnicity, %	
White	75.9%
Aboriginal	2.1%
Other	22.1%
Health behaviour clusters	
Traditional School Athlete	27.9%
Inactive Screenagers	44.9%
Health Conscious	20.0%
Moderately Active Substance Users	7.2%
Weekly spending money, %	
None	18.6%
$1 to $20	38.2%
$21 to $100	24.3%
More than $100	5.1%
"I do not know"	12.9%
Weight status, %	
Normal weight	76.9%
Overweight/obese	23.2%
Body Mass Index (BMI), in kg/m^2	
2012	21.26 (3.35)
2013	21.89 (3.44)
2014	22.26 (3.49)

COMPASS School and neighbourhood characteristics at baseline (2012-2013) (N=41)

School-level variables are presented in Table 20. Only 2 of the 41 schools were categorized as rural. At baseline, only 25% of schools had a physical activity policy in place; although mandated in 2011, only 51.2% of schools indicated having a healthy eating policy. The programs and practices most frequently present in schools included varsity sports (100% of schools), physical activity events (38 of 41 schools), programs to understand nutrition (40 schools), and cooking classes (38 schools). Between baseline and Y_2 of COMPASS, 28 schools incorporated additional physical activity programs, while 21 schools added healthy eating practices. While some schools indicated changes to physical activity (6) or healthy eating (7) policies, the actual modifications made were unclear. Some examples of program or practice changes made in COMPASS Schools can be seen in Table 4.

Table 20. School-level characteristics and the proportion of students exposed to each school characteristic in year 1 (baseline) of the COMPASS Study (2012-2013) and modifications made between year 1 and year 2 of the COMPASS Study (2012/13 to 2013/14) (N=41)

School-level characteristic	**# Schools in Y_1 (N=41)**	**% of students exposed to school-level characteristic**

School location		
Large Urban	21	65.1
Medium Urban	5	12.2
Small Urban	13	21.2
Rural	2	1.6
Baseline school-level factors		
Physical activity policy	10	25.3
Fitness club partnerships	20	47.2
Intramurals	25	55.9
Non-competitive sports	28	73.9
Physical activity events	38	90.3
Varsity sports	41	100.0
Healthy eating policy	21	50.1
Breakfast programs	37	89.7
Cooking classes	38	91.8
Gardening	15	41.5
Field trips to farmers markets	18	43.8
Media literacy	33	76.5
Trips to grocery stores	22	49.9
Programs to understand nutrition	40	97.5
Modifications to school-level factors between baseline and year 2		
Physical activity Policy change	6	13.6
Physical activity Practice change	28	68.0
Healthy eating policy change	7	17.1
Healthy eating practice change	21	46.4

*Note: % of students will not always match # of schools, because the number of students per school varied

The majority of COMPASS schools had existing physical activity and nutrition programs and policies in place, and after one year of COMPASS, more than half of the schools made improvements to their physical activity or healthy eating environments.

Table 21. Characteristics of the school program and policy environment by weight category in the baseline COMPASS sample (N=41 schools)

	# schools	Normal Weight (% students)	Overweight/obese (% students)	Chi-square
Cooking classes				P=0.0022
Yes	38	76.3%	23.7%	
No	3	83%	17%	
Gardening				P=0.0021
Yes	15	79.0%	21.0%	
No	26	75.3%	24.7%	
Field trips to				

farmers markets				
Yes	18	77.1%	23.0%	P=0.7710
No	23	76.7%	23.3%	
Media Literacy				P=0.1226
Yes	33	76.3%	23.7%	
No	8	78.5%	21.5%	
Trips to grocery stores				P=0.7615
Yes	22	76.7%	23.3%	
No	19	77.0%	23.0%	
Programs to understand nutrition				P=0.0354
Yes	40	77.1%	22.9%	
No	1	69.1%	31.0%	

Out of interest, I examined the effect of baseline school policies and programs on students' BMIs (Table 22), comparing schools with to those without programs and policies.

I first examined the bivariate and multivariate relationships between each individual school policy and program at baseline and BMI trajectory. I then examined the combined effects of (1) physical activity programs and (2) healthy eating practices on BMI. Finally, I tested the effect of all (3) obesity-related school policies and programs combined (i.e., "comprehensive") on BMI by taking a sum of all programs and policies and investigating this as a continuous predictor variable. Models that included more than one school policy or program considered each item independently while controlling for all others. In the univariate analysis, *gardening* was significantly associated with BMI at baseline – youth attending schools that offered gardening programs had lower BMI values than those without gardening programs (β= -0.454 kg/m^2). Once student and school-level characteristics were added to the model, gardening no longer remained significant. When considering all school level factors in one model, only school events that promote physical activity was significantly associated with BMI in youth (β=-0.564 kg/m^2), suggesting that BMI at baseline varied significantly among those attending schools that promote physical activity through events. See Table 22 for these model results.

Table 22. Results of linear mixed effects models, modeling the effect of baseline policies/programs on BMI trajectories of youth in the COMPASS Study (2012/13 to 2014/15)

Variable	Model 1: Univariate baseline	Model A[¶]	Model B[§]
	β (SE)	β (SE)	β (SE)
Physical Activity			
Policy	-0.123 (0.207)	-0.099 (0.154)	
Programs			
Intramurals	0.255 (0.178)	0.0320	-0.0054 (0.123)
Fitness club partnerships	0.036 (0.179)	-0.116	-0.0191 (0.131)
Non-competitive sports	-0.297 (0.196)	-0.115	-0.200 (0.147)
Physical activity events	-0.180 (0.324)	-0.564*	-0.614 (0.227)*
Healthy Eating			
Policy	0.0441	-0.210	
Breakfast program	0.3362 (0.292)	-0.087	
Practices			
Cooking classes	0.5250 (0.325)	0.068	0.027
Gardening	-0.4535 (0.169)*	-0.223	-0.151
Trips to farmer's markets	-0.1399 (0.180)	-0.237	-0.257
Media literacy	0.3137 (0.213)	0.089	0.231
Trip to grocery stores	0.1572 (0.179)	-0.119	-0.041
Programs to understand nutrition	-0.5373 (0.554)	-0.248	-0.391
Comprehensive (all physical activity and healthy eating factors)		-0.0396 (0.0262)	

[¶]Model A: the independent effect of each school program, policy, or practice on BMI trajectory, not controlling for all others

[§]Model B: all items entered into the model together, thereby considering the effect of multiple programs on BMI trajectories

Both models A and B controlled for relevant socio-demographic variables (gender, grade, race/ethnicity, SES, and school location).

Appendix H: Frameworks to evaluate school environments

The Environmental Research framework for weight Gain prevention (EnRG) Framework explains that the environment can influence behaviour both directly and indirectly, with behavioural and personal factors moderating the causal path between environment and behaviours. Using this framework may help researchers understand the causal mechanisms that link the environment to physical activity and diet (and subsequently, energy imbalance and obesity). It can also help to identify which factors are important, specifically related to when, how, and for whom environmental factors are influential (Kremers, De Bruijn, Visscher, Van Mechelen, De Vries, & Brug, 2006).

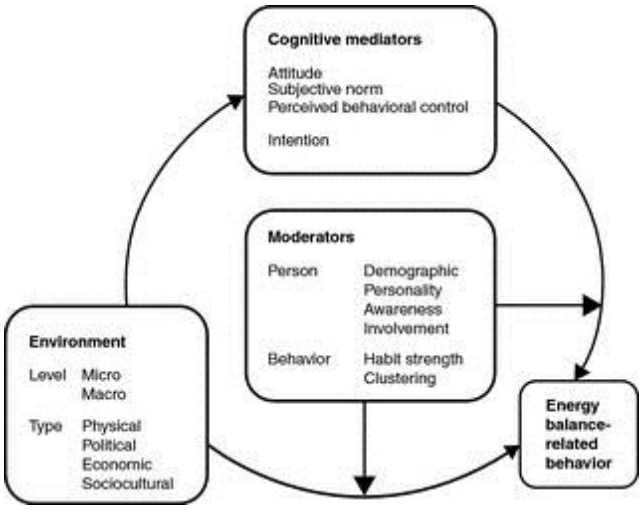


Figure 17. Environmental Research framework for weight Gain prevention (EnRG)

(Kremers, De Bruijn, Visscher, Van Mechelen, De Vries, & Brug, 2006)

The ANGELO Framework can be applied to the "Environment" box in the EnRG framework; ANGELO divides environment into types of influence – physical (what is available), economic (costs), political (rules), and sociocultural (attitudes and beliefs). There are also two levels (or sizes) of influence – micro-environmental settings and macro-environmental settings. Micro-environmental settings include schools, workplaces, homes, and neighbourhoods. These micro-environments are influenced by the macro-environments, made up of health systems, governments, and the food industry (Swinburn, Egger, & Raza, 1999). When the types and levels of environment cross, it forms a grid with four types on one axis, and two sizes of environments on the other. The ANGELO Framework (see Figure 18) can help to categorize determinants of behaviours and identify current environmental

interventions targeting these behaviours. Its purpose is to help understand the obesogenicity of environments, and to be used as a tool to prioritize which environmental element requires research and intervention (Swinburn, Egger, & Raza, 1999). Unlike the RE-AIM framework below, it is most useful for the needs analysis and problem identification stages, while RE-AIM is most useful during and after implementation of an intervention (Glasgow, Vogt, & Boles, 1999).

	Environment type			
Environment size	Physical	Economic	Political	Socio-cultural
Micro-environment: **school**	Cafeterias serving food	Cost of food within and outside of school	Physical education and nutrition policies in schools	School culture that promotes health behaviours
Macro-environment: **Ministry of Education**				

Figure 18. ANGELO Framework with example

(Swinburn, Egger, & Raza, 1999)

The RE-AIM framework is aligned with the social-ecological model and community based interventions. If applied to these school-based interventions, its underlying principles suggest that the interventions' impact is based on the effect of five dimensions:

1. Reach: measure of participation, defined by the percentage and risk characteristics of those impacted by the interventions
2. Effectiveness: measuring if the program achieved its intended goals/outcomes (more long-term measure)
3. Implementation (fidelity): extent to which a program is delivered as intended. This is hard to identify using natural experiments, especially those measured using the SPP (lack of detail). Implementation fidelity is an important indicator for measuring the alignment between a planned program and actual program implementation, often referred to as *adherence*. By measuring a program's implementation fidelity, we can increase the validity of our interpretation of program effectiveness. Assessing implementation fidelity provides the opportunity to explain what occurred throughout the program, rather than just what was planned. It also helps to contextualize the findings of a later outcomes evaluation. For example, if a long-running program was effective in some communities but not others, knowing the community-specific implementation might help understand the differences in effectiveness.
4. Adoption: proportion and representativeness of settings that adopt the interventions

5. Maintenance: the extent to which the modifications, such as policies, are maintained over time to become reasonably stable

Using RE-AIM would allow researchers to produce the necessary evidence to help policy-makers and program funders make decisions about long-term investment in programming, and to help evaluators articulate the environments in which interventions are most likely to be successfully implemented.

The following figure (Figure 19), developed by Domitrovich and colleagues, conceptualizes an intervention as being embedded within the socio-ecological model, with implementation quality at the centre (Domitrovich, et al., 2008). More specifically, it is a multilevel conceptual framework split into three levels, all of which are interdependent and can influence the quality of intervention implementation and subsequently influence student outcomes: (1) macro level, (2) school level, and (3) individual level. The article refers to a relevant example: administrative support or a healthy school environment may influence staffs' willingness to implement innovative intervention, attendance at training, and willingness to discuss challenges faced. These teachers, exposed to health promoting environments, may feel more empowered and have greater efficacy, which will affect the quality of their intervention implementation.

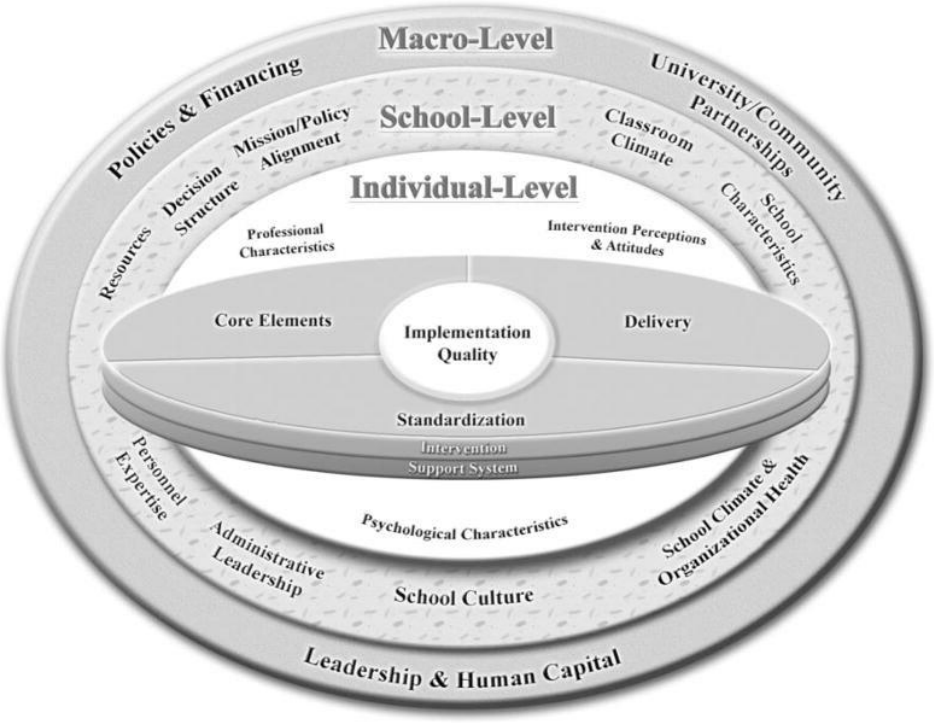


Figure 19. Multi-level model that considers factors affecting implementation quality