Association between Public Health Unit Engagement in Secondary Schools and Per Capita Public Health Spending and Adolescent Substance Use

by

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ABSTRACT

Background

Based on the socio-ecological model of health, government institutions have an important role in shaping adolescent health. Public health units (PHUs) are one such institution. PHU decisions on community collaboration and resource allocation may have important downstream consequences on population health. Although studies are sparse, descriptive and cross-sectional studies suggest that PHU engagement in secondary schools may benefit adolescent health. The first objective of this study was to investigate the association between PHU engagement in secondary schools and adolescent substance use over time. Additionally, PHU spending has been shown to be associated with population health outcomes. Although the evidence is mixed, several studies find that greater PHU spending is associated with improved population health. The second objective of this study was to investigate the association between per capita PHU spending and self-reported substance use among Canadian adolescents.

Methods

To investigate the association between PHU engagement and adolescent substance use, a longitudinal analysis was completed using data from the Cannabis, Obesity, Mental Health, Physical Activity, Alcohol Use, Smoking, and Sedentary Behaviour (COMPASS) study, which was conducted in Ontario, Alberta and British Columbia. 16,575 students in grades 9-12 in 68 schools who participated in year 5 of the COMPASS study (2016/17) were followed until year 7 (2018/19). Students answered survey questions on demographics and on their substance use behaviour. School representatives answered survey questions about school-level engagement by their local PHU in addressing substance use. To investigate the association between PHU

spending and adolescent substance use, a cross-sectional analysis was conducted using data from year 7 (2018/19) of the COMPASS study as well as PHU per capita spending information from the Ontario Public Health Information Database (OPHID). Statistical analyses were conducted for a sample of 29,056 students in grades 9-12 in 61 schools across Ontario. Substance use was measured as the self-reported use of alcohol overall, alcohol binge drinking, cannabis use, cigarette use and e-cigarette use, at least once per month on average.

Results

Approximately 50% of the study samples were female and the majority identified as being White. In 2016/17, 65% of schools reported PHU engagement in addressing substance use. Methods of PHU engagement ranged from the provision of informational resources to leading prevention programs. With respect to PHU spending, the distribution of expenditure values was right-skewed. Per capita spending ranged from $54.07 to $224.95, with a median spending amount of $89.62 and a mean of $95.96. As an overall measure fixed at baseline, PHU engagement was not associated with adolescent substance use. However, different methods of PHU engagement were associated over time with different types of substance use. For example, adolescents exposed to PHU-school joint problem solving/program implementation had lower odds of cannabis and e-cigarette use at baseline (adjusted odds ratio (AOR): 0.43; 95% CI: 0.25, 0.76 and AOR: 0.38; 95% CI: 0.20, 0.72, respectively), but a larger increase in the odds of cannabis and e-cigarette over time (AOR of interaction terms: 1.80; 95% CI: 1.13, 2.86 and 2.58; 95% CI: 1.69, 3.96, respectively), compared to adolescents exposed to no PHU engagement. Adolescents exposed to PHU-led programs had a smaller increase in cigarette use over time compared to those not exposed, suggesting a protective association (AOR of interaction term: 0.67; 95% CI: 0.46, 0.97). With respect to PHU spending, the highest quartile of expenditure

compared to the lowest quartile was significantly associated with higher odds for alcohol use (AOR: 1.41, 95% CI: 1.04, 1.91), alcohol binge drinking (AOR: 1.71, 95% CI: 1.18, 2.48), and cigarette use (AOR: 2.19, 95% CI: 1.23, 3.91), while the second highest quartile was associated with lower e-cigarette use (AOR: 0.74, 95% CI: 0.56, 0.98).

Conclusion

PHUs have potential to address adolescent substance use through evidence-informed engagement at secondary schools, however further research is required to examine how different methods of engagement may impact students differently. The highest quartile of PHU spending was associated with higher alcohol and cigarette use in this study. Further research is needed to explore the direction of this association and potential pathways where intervention can occur.

PREFACE

This thesis is an original work by Urvi Rai under the supervision of Dr. Roman Pabayo and thesis supervisory committee members Dr. Ambikaipakan Senthilselvan and Dr. Elaine Hyshka. The idea for this research came from Dr. Roman Pabayo. Thesis conceptualization, development of the research questions and the methodological approach was completed by Urvi Rai under the guidance of Dr. Pabayo and supervisory committee. This research was conducted as part of a larger study in the EMERGE Research Lab under University of Alberta Ethics Project ID: Pro00099672. This research has generously been funded by the Canadian Institutes of Health Research, the University of Alberta School of Public Health, and the Alberta Graduate Excellence Scholarship.

U. Rai made substantial contributions to the study design, analytic plan, data cleaning and analysis, results interpretation, as well as drafting and revising the thesis. Dr. Pabayo acquired funding as well as all data used in this thesis. Dr. Pabayo made a substantial contribution to conception and study design, analytic plan, interpretation of data, and multiple critical revisions of this thesis. Dr. Senthilselvan made a substantial contribution to the analytic plan, interpretation of data, and a critical revision of this thesis. Dr. Elaine Hyshka made a substantial contribution to the analytic plan, results interpretation, and critical revision of the thesis.

No part of this thesis has been previously published, although Chapters 3 and 4 will be adapted as manuscripts and submitted for publication.

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CHAPTER 1: INTRODUCTION

This chapter provides the epidemiology of adolescent substance use in Canada, followed by a description of two theoretical frameworks that have guided this thesis work. Next, this chapter discusses risk and protective factors associated with adolescent substance use.

1.1 Epidemiology of adolescent substance use

Adolescent substance use is an important public health concern. According to the 2013 Global Burden of Disease study, substance use accounted for 4-15% of disability-adjusted life years among 15-19 year olds in North America.[1] Substance use refers to the consumption, inhalation, injection, or other use of alcohol, cannabis, tobacco/nicotine, and various other legal and illegal drugs, including opioid pain relievers, stimulants, and sedatives.[2] Substances may be used for a number of purposes, including their therapeutic effects in the case of prescribed pharmaceuticals, their significance in religious practice or ceremony, for recreational use, or as a means of coping with pain, stress, and mental illness.[2] Health Canada describes a spectrum of substance use with five levels: abstinence, beneficial use, lower-risk use, higher-risk use, and substance use disorder (Figure 1).[3] "Higher-risk" use is described as use that has a negative impact on the user's health or social relations.[3] Substance use in this thesis will focus on monthly use of alcohol, cannabis, cigarettes and electronic cigarettes (e-cigarettes) in a population of secondary school students aged 15-19 years.

The most common substances used by Canadians aged 15-19 are alcohol and cannabis.[4] According to the 2019 Canadian Alcohol and Drugs Survey (CADS), 46% of adolescents aged 15-19 used alcohol and 22% used cannabis in 2019.[4] According to the 2019 Canadian Tobacco and Nicotine Survey (CTNS), 5% of adolescents aged 15-19 reported being current (daily or occasional) cigarette smokers and 15% reported being current users of e-cigarettes or other vaping devices.[5] It is important to note that in Canada, all four of these substances are legal for use by those 18 or 19 years and older, depending on the region, which affects the prevalence of use around this age range.[6,7] For comparison with the 15-19 age group, among adolescents aged 12-17 years, an estimated 25.6% used alcohol in the past-year.[8]

The prevalence of adolescent substance use has changed over time. 2013 was the first year that the CADS was administered and since then, the past-year prevalence of alcohol use among adolescents aged 15 to 19 years has decreased (60% to 46%), while cannabis use has

remained approximately the same (23% to 22%), and the prevalence of current cigarette smoking has decreased (11% to 5%).[9] Of concern, the prevalence of current e-cigarette use among adolescents aged 15-19 years has increased, based on the CTADS sample, five-fold (3% to 15%).

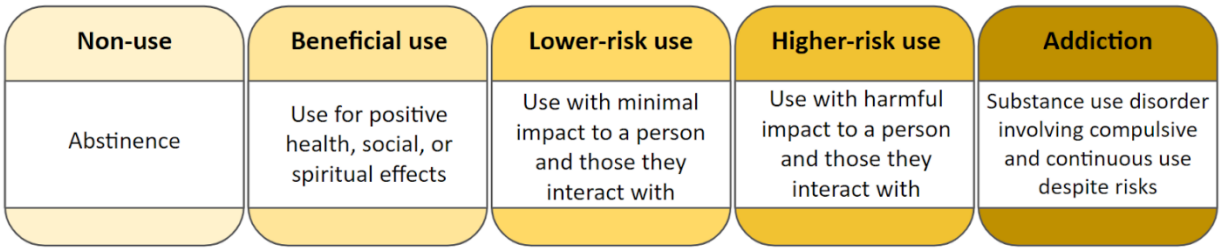

Figure 1.1. Health Canada Substance Use Spectrum. Adapted from Health Canada 2022.

Higher-risk substance use by adolescents is of public health concern because of the consequences it can have on adolescents' physical and developmental health. Physical harms due to substance use vary by type of substance, dosage, frequency of use, context of use and mode of administration.[10,11] Higher-risk use can be described as consuming a high dosage in one instance (e.g. binge drinking alcohol), frequent or prolonged use (e.g. daily smoking), using substances when alone, or using substances while operating a vehicle.[10,11] Different modes of administration result in different risks, whereby smoking/inhalation may cause respiratory problems while injection use may increase the spread of blood-borne diseases. One review of Canadian studies suggests that there may also be a link between substance use and death by suicide.[12] In addition to physical harms, substance use can impact healthy growth, given that adolescence is a significant time for many aspects of development, including brain development.[13–16] Heavy substance use in the form of alcohol, cannabis or cigarette use has been linked with structural and functional damage to the developing brain, along with deficits in cognitive function.[14,17–20]

Substance-related harms may be acute or long-term, and may be due to the substances themselves, risk behaviours associated with substance use, or from the negative impacts of policies, such as criminalization, designed to control substance use.[21–24] Acute harms can include blackouts, drug poisoning, accidents and injury.[10,11,23] In 2017/18, among youth ages 10 to 24, the rate of hospitalization due to substance use was 364 per 100,000, and represented 5% of all youth hospitalizations.[25] It is estimated that for every hospitalization due to substance use, there

are five emergency department visits.[25] From 2011 to 2019, one study found that 60% of all self-harm related emergency department visits in Canada involved some form of substance use, and 37% resulted in hospitalization.[26] Notably, the median patient age was 16.6, suggesting that many of these hospitalizations due to self-harm with substance use occurred among youth. Alcohol and cannabis are commonly associated with substance-related hospitalizations such as those due to traffic accidents and injuries.[10,25] Alcohol use can also have longer term consequences in the case of regular or heavy use without intervention, such as high blood pressure, obesity, and alcohol-related liver disease.[5–10] Long term consequences of cigarette smoking include respiratory or vascular diseases and lung cancer.[10] Additionally, substance use in adolescence is associated with a higher likelihood of problematic substance use in young adulthood.[27,28]

Risk behaviours associated with substance use include use of other substances concurrently (polysubstance use), school absenteeism and poor achievement, aggression/violence perpetration or victimization, unprotected sex or sexual victimization, and impaired or distracted driving.[11,21–23,29–31] Given that the leading cause of mortality among 15-19 year olds in Canada is unintentional injuries/accidents, one risk factor for which is intoxication, adolescent substance use is a particularly important and urgent issue for public health units to attend to.[32]

Notably, the policies aimed at preventing substance use sometimes unintentionally cause harm to adolescents using substances.[24] Specifically, the criminalization of drugs results in a lack of regulation and quality control, increasing the chances of adolescents using contaminated products that can be even more harmful. Additionally, adolescents' experiences with law enforcement, and subsequently with other offenders, can be traumatic. Moreover, criminalization can result in short- and long-term stigmatization and hampering of career opportunities, thus impacting an important social determinant of health.[24,33]

1.2 Relevant frameworks

This thesis will apply two frameworks to the study of adolescent substance use: the life course model and the socio-ecological model.[34,35] These models were chosen because they emphasize the interaction between adolescents at a developmentally significant stage in their lives, with the social contexts in which they live and grow.[16] The life course model describes trajectories and transitions.[34] Trajectories are long-term, persisting or changing patterns in

behaviour, and transitions are discrete, shorter-term events that shape trajectories.[34] For adolescents, secondary school is a time of transition between childhood to adulthood, as they are likely to form new relationships, partake in new activities, and take on new responsibilities or a new level of independence.[34] Significant brain development, physiological growth, and maturation also occurs during this period.[15] Simultaneously, risk-taking and sensation seeking behaviours are common, and normal. Cigarette, alcohol and other substance use often begins in adolescence, most commonly between the ages of 15 and 18.[34] Interventions that prevent or delay the onset of substance use at this age, or reduce harm among those who have already initiated use, are important to protect and promote health.

To positively impact developmental and behavioural trajectories, it is useful to understand the factors that place adolescents at risk of substance use, and factors that can be protective against substance use. The social determinants of health, or "the circumstances in which people grow, live, work, and age" play an important role in shaping adolescent health behaviours, including substance use.[36] The socio-ecological model described by McLeroy et al. (1988) offers a framework by which to study the social determinants of adolescent substance use. It consists of five levels: intrapersonal, interpersonal, institutional/organizational, community, and public policy.[35] Intrapersonal factors are individual characteristics including age, gender, race, education, socioeconomic status, as well as personal values and beliefs. Interpersonal factors occur between individuals, and refer to relationships with family, peers, and community members. Institutional factors include characteristics of social structures such as educational institutions, religious institutions, and public service organizations. Institutional factors may influence adolescents through their formal and informal rules, expectations, or processes. Community level factors can be studied in two ways. Community can reflect the relationships and networks between institutions, *or* the characteristics of the natural and built environments that individuals interact with. Community level factors include partnerships between educational institutions and health departments, social cohesion, and neighbourhood safety. Finally, public policy refers to the local, provincial/state, or federal laws and policies that shape the social structures and systems that influence the other four levels of the ecological framework. Factors at each level interact within and between levels to create the conditions in which adolescents grow and develop.

Any discussion of the social determinants of health is incomplete without also considering inequities in the distribution of social determinants in a population. Populations experiencing poverty, racism, neocolonialism, or other forms of discrimination are often denied equal opportunity or access to social goods such as education and health care.[37] At the community level of the socio-ecological model, they may experience greater social exclusion, low neighbourhood safety, and low access to health or educational resources. Poor access to social determinants of health result in poor health outcomes among these populations, creating health inequities - avoidable disparities in health across the population.[37] At the highest level of McLeroy's socio-ecological model, public policy has the power to address health inequities by ensuring that healthful living conditions and social goods are equitably distributed. Public policy has the power to dismantle institutional processes that result in systemic discrimination, social exclusion and consequently, health inequities.

1.3 Risk and protective factors for adolescent substance use

Based on the socio-ecological model of health promotion, determinants for high-risk substance use can occur at the intrapersonal, interpersonal, institutional, community, and policy levels.[35] The following is a broad overview of risk and protective factors. This overview is a simplification of otherwise complex psychosocial processes. Factors associated with adolescent substance use depend on the type of substance (e.g., alcohol, illicit drugs, etc.), the dose taken, frequency of use (e.g., occasional vs heavy use) and whether adolescents are using alone or in a social setting.[10,11]

Intrapersonal factors include beliefs and attitudes towards substance use.[29,38] Disapproval or perception of harm are protective against substance use, while previous positive experience and sensation seeking attitudes predict future use. Individual characteristics such as age and gender are related to substance use whereby adolescents who are older and identify as males are more likely to use substances.[30,39–41] On the other hand, high self-esteem and psychosocial well-being are protective factors.[29,40] Additionally, school interest and strong school performance are both protective against substance use.[29] Although physical activity is another determinant of adolescent substance use, evidence for the direction of association is mixed, depending on the substance studied and the type of physical activity. For example, some studies report a positive association between physical activity and high-risk alcohol use (binge drinking) but a negative

association between physical activity and cigarette use.[40,42] Patrick and Schulenberg (2014) report that physical activity in the form of general exercise is associated with a decreased odds of alcohol use whereas physical activity in the form of sports team participation is associated with increased alcohol use.[29] Intrapersonal factors also include characteristics of adolescents' families. There is evidence that parental education and family affluence are associated with adolescent alcohol, illicit drug, and cannabis use, though the direction and strength of association may differ by the population studied.[43–45] Spending money, as an indicator for socioeconomic status, is also associated with substance use. Those students with more weekly spending money have higher odds of substance use.[30,42,46]

Interpersonal factors are among the strongest predictors of substance use.[29,35,38,47] Interpersonal factors are those that reflect the influence of adolescents' peers, family, and adults outside of family. Peer use or approval of substances, *perceived* peer use and approval of substances (the latter of which is often overestimated), along with parental use or approval of substances, are all risk factors for adolescent substance use.[29,38,47] Conversely, family bonding, family support, parental supervision, and healthy relationships are protective against substance use.[29,30,38,39,48] Adolescents spend a significant portion of their day at school and interact with members of the school community, including peers and educators. Connectedness with their school community or involvement at school are protective factors against adolescent substance use.[46,49] Returning to findings by Patrick and colleagues, sports participation was found to be associated with an increased odds of alcohol use. This is likely because of the social aspect of sports participation whereby social norms, along with reduced parental supervision, may contribute to an increased likelihood for alcohol use.[29,38]

Institutional factors are characteristics of social institutions or organizations with processes and rules that impact adolescent health. Researchers identify roles for schools, universities, public health units, religious institutions, and media companies in influencing adolescent substance use behaviours. For example, school policies and programs have the potential to protect against high-risk substance use by directly addressing the issue, or by addressing factors associated with substance use, such as poor mental health or physical activity.[40,41,50,51] Universities can provide research capacity to guide evidence-informed program development and program evaluation.[52,53] Public health units can address adolescent substance use by providing substance use assessment, treatment or referral services, harm reduction in the

form of needle exchange services, and counselling.[54,55] With respect to religious institutions, adolescent involvement in religious institutions has been found to be protective against substance use.[29,56] Exposure to media and advertising that presents substance use as a popular, enjoyable or relaxing activity is a risk factor for substance use.[56,57]

Community level factors reflect the partnerships, or lack thereof, between institutions or organizations.[35] For example, public health units may collaborate with schools to provide informational resources or to support school-based programs and services that address adolescent substance use.[54,55,58,59] Community level factors also reflect area level characteristics such as poverty rate, unemployment rate, neighborhood availability of drugs, perceived neighborhood safety, and income inequality.[10,35,60–62] Higher poverty rates, unemployment rates, neighborhood availability of drugs, and low perceived safety are risk factors for substance use.[10,35,61] There is mixed evidence for the impact of income inequality on adolescent alcohol use. One study of province-level income inequality found no association, but a study of nation-level income inequality and another of neighbourhood-level income inequality both found find evidence that higher income inequality may be associated with increased adolescent substance use.[60,63,64]

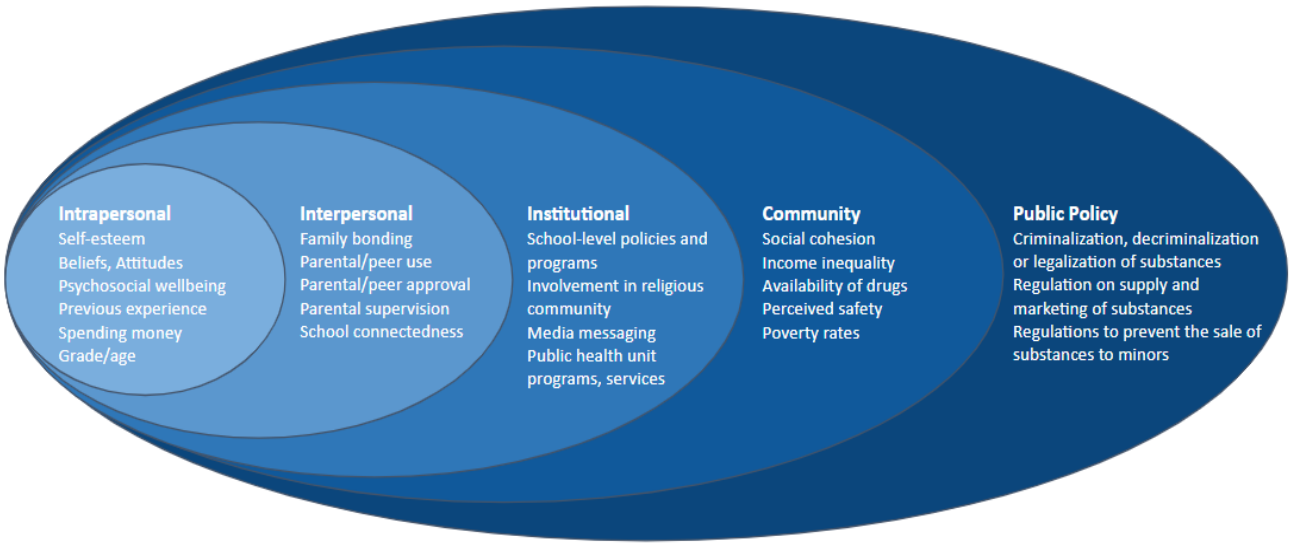

Figure 1.2. Adapted from the American College Health Association. Based on conceptual framework by McLeroy, K. R., Steckler, A. and Bibeau, D. (Eds.) (1988).

Finally, social and economic policy may have a role to play in preventing adolescent substance use. An example is the laws and regulations preventing the sale of substances to youth.

The decision to take punitive or rehabilitative action on youth engagement in substance use is another important factor.[54,65] Policies may also include those regulating the supply and marketing of substances, or the legalization of previously illegal substances such as cannabis in Canada, as of October 2018.[6,65] Klein et al. compare regulatory measures taken around the world in regards to e-cigarette flavours, sales and advertising to adolescents for the purpose of preventing or reducing uptake and vaping related harms.[65] Economic policy involves decisions on investment in public health, and may be reflected by annual public health unit expenditure on programs and services.

Public health interventions can occur at any level of the socio-ecological model to support the mitigation of risk factors or strengthen protective factors against adolescent substance use. This thesis will focus on the community and public policy levels, and specifically consider the roles of local public health units. Public health units (PHUs) have the primary objective of protecting and promoting the health of communities within their jurisdiction.[66] This involves promoting social, mental and physical health and wellbeing, preventing illness and injury, and reducing health inequities.[67,68] PHUs accomplish these goals by implementing public health programs and services, conducting disease surveillance, offering consultation services or health education, and more.[67,69,70] At the community level, PHUs collaborate with other sectors such as the social service or educational sectors.[58,59,67,71] When addressing adolescent health, schools are an important potential setting for collaboration.[71] Given the amount of time adolescents spend in school, PHU-school partnerships offer a valuable point of contact with adolescents and opportunity to positively direct their developmental and behavioural trajectories.

As illustrated by the socio-ecological model, adolescent health and substance use is impacted by numerous factors at each level of society. In addition to targeting adolescents directly, PHUs influence adolescent health by addressing the health of their communities more broadly. PHUs may run programs for the healthy growth and development of young families, ensure safe food and water supplies, improve access to the social determinants of health, support poverty reduction, support communicable disease prevention, and advocate for healthy public policy, to list a few examples.[69] One key requirement for a successful public health system is sufficient resources to carry out public health activities.[66,72] Governments are responsible for making critical decisions in regards to allocation of limited resources. In times of austerity, governments may reduce funding from some areas to invest more in others. In the case of

England following the 2008 recession, or the province of Ontario in Canada in 2019, times of austerity have led governments to propose divesting from local authorities of public health.[73,74] In 2019, the government of Ontario announced a plan to reduce the provincial contribution to cost-shared public health programs offered by local PHUs.[74] It is important that funding decisions are context-sensitive and evidence-informed. To understand the impact that spending cuts could have on population health, it may be useful to explore the association between public health spending and population health outcomes, such as adolescent substance use.

This thesis will study the role of PHUs in addressing adolescent substance use by looking at two indicators: (1) the collaboration of PHUs with secondary schools to address substance use, and (2) PHU per capita spending on public health activities. Referring again to the socio-ecological model of health, the first indicator reflects a community level intervention while the second indicator reflects a policy level factor, to address adolescent substance use.

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CHAPTER 2: LITERATURE REVIEW

This chapter provides two narrative reviews. The first is a review of the literature on PHU engagement in secondary schools. After a brief discussion of public health involvement in schools broadly, this literature review describes the specific role of local-level PHUs. The review includes four papers that focus on adolescent substance use and the role of PHUs in capacity building and service provision. Next, this chapter offers an overview of public health structure and responsibilities in the Canadian provinces of Ontario, Alberta and British Columbia, along with the role of public health in school health specifically.

The second narrative review focuses on public health spending. The aim of this review is to summarize association studies between PHU spending and population health outcomes. Each study is described in terms of its study design, exposure and outcome of interest, and key findings, along with strengths and limitations of the research. Although there are no association studies between PHU spending and adolescent substance use, the narrative review is followed by a description of select studies that have looked at public health or social service spending broadly and its association with substance use in the general population. Chapter 2 concludes with a discussion of the gaps in the literature and how this thesis will aim to fill those gaps.

2.1 Background: Public health engagement in schools

Public health authorities engage with schools in a variety of ways, including program implementation, problem solving, and information dissemination.[1–4] If engaging with existing school-based health programs, public health staff can improve the quality and sustainability of these programs by offering training or tools to improve capacity.[2,5–8] Public health engagement can also support the promotion of health equity. The school setting allows public health staff to reach students who may not otherwise have access to preventative care or health promotion programming due to their socioeconomic status or membership in a marginalized community.[3,6] School-based programming may occur in areas such as oral health, vision health, immunization, sexual and reproductive health, obesity prevention, healthy eating, bullying prevention, mental health, substance use, physical activity and addressing sedentary behaviour.[2,6,9–11]

As an example, school immunization programs aim to administer routine and catch-up vaccines for adolescents, including Human Papillomavirus (HPV) vaccines and vaccines in response to influenza outbreaks.[12,13] They also offer an opportunity to evaluate and improve

knowledge regarding immunization, reduce children's needle-related anxiety, and build trust among parents by engaging with them in collaboration with trusted school staff.[12,13] School-based HPV vaccine uptake has been shown to be higher when the program was implemented as a joint responsibility between the school and local health departments, as compared to being led by the health department alone, and when teachers were involved in vaccine promotion or program coordination.[12] This may be because teachers, as compared to external or unknown professionals, are likely more familiar to and trusted by students and their parents. Strong relationships between representatives from schools and local PHUs are considered key to program success.[12]

Preventative oral health services in schools are another example of public health collaboration with schools. Preventative oral health aims to reduce the risk of dental caries, provide instruction on oral hygiene, ensure healthy eating, and improve oral health overall.[14,15] These services are offered in dental clinics within schools where they are more accessible to children and youth than community clinics that may be far in distance and/or require parents to take time off work to visit. These school-based programs may involve teaching good oral hygiene practices to children, training teachers and parents to reinforce these lessons, screening children for illnesses, and providing tools to schools (e.g. educational posters, pamphlets) or students (e.g. toothbrush and toothpaste).[14,15]

Public health units may also be involved in school-based health centers (SBHC). SBHCs can provide primary healthcare services in a range of areas, including dental health, mental health, reproductive health, drug treatment services, and treatment and management of chronic conditions.[16–18] However, SBHCs may also provide preventative services and health promotion programs. These include communicable disease control and prevention, STI screening and education, vision health screening, and substance use counseling.[16,17,19]

The specific body of public health that is involved in schools may vary. Public health resources and services may be provided to schools by a national body such as the Public Health Agency of Canada (PHAC) or the Centers for Disease Control and Prevention in the US. Alternatively, resources and services may be provided by provincial/state departments of public health, or local health departments specific to a region, city, township, or county.[7,8,12,20,21] In Canada, PHAC serves as an advisor, supports research in school health, and offers funding for initiatives in school health.[21] In the US, state level public health departments may offer funding, technical assistance, support in program implementation, training for health or non-health

professionals working in schools, or their expertise in the form of consultation and policy development.[3,5,7,22,23] This thesis will focus on the role of public health units at a local level in school-based public health initiatives.

2.2 Narrative review: Public health unit engagement in schools

To explore the literature on PHU engagement in schools, a search was conducted using terms for local public health bodies ("public health unit" OR "health department" OR "health authority") combined with search terms relating to collaboration ("collaboration" OR "support" OR "engagement" OR "partnership"), and combined with "school." Databases searched were CINAHL, PsycInfo, Medline, PubMed, and Child Development and Adolescent Studies. Only articles written in English were included. Papers on public health programming in schools were excluded if they did not clearly mention whether local public health was involved or did not describe a role for local public health. For simplicity, any local public health office, health department, health authority or otherwise, will be referred to herein as the local public health unit, or PHU. Twelve studies were identified. Ten studies took place in the United States and two in Canada. Eight are descriptive studies and four are cross-sectional association studies. All were published between 2006 and 2022. A summary of the twelve studies is shown in Table 2.1 and a narrative description of the literature can be found in Appendix A.

Briefly, PHUs have taken a diverse range of roles in their collaboration with schools. Some key roles identified in the literature were surveillance and data collection, capacity building, program or service delivery, and joint problem solving. The most common was capacity building in the form of resource provision and information dissemination. Health outcomes targeted in PHU-school collaborations include substance use, obesity, physical activity, sexual health, and COVID-19 incidence.

There were four studies found that explore the role of PHUs in schools and adolescent substance use. VanderWaal et al. (2006) and McBride et al. (2008) identify factors that are associated with PHU engagement in schools, while Vermeer et al. (2021) and Burnett et al. (2022) study the association between PHU engagement and health outcomes.[1–4] Notably, while the majority of research on PHU collaboration with schools is from the United States, Burnett et al. (2022) and Vermeer et al. (2021) offer a Canadian perspective.

VanderWaal et al. (2006) investigate the role of PHUs in offering drug treatment services to adolescents in school health clinics, juvenile drug courts, or other community agencies.[4] The potential roles that PHUs may have played in schools were categorized as: serving as a referral agent for youth who use drugs; providing screening or treatment for youth who use drugs; providing resources dedicated to assessing alcohol, tobacco, and other drug prevention/treatment needs; providing resources dedicated to youth illicit drug use treatment and/or counseling; or any of the previously listed categories. Just over half of study participants in a nationally representative sample of American youth had their local PHU involved in school health clinics. For the majority of youth, their local PHU provided resources to assess substance use prevention or treatment needs. Researchers were interested in four area level factors: community income, urbanicity, concentration of the youth population and community racial composition. The first three factors were unrelated to the likelihood of being served by a PHU engaged in school health clinics, however racial composition of the community was significantly associated with PHU engagement. Youth who lived in communities where the size of the African American population was larger than the national average, had a higher likelihood of being served by PHUs that were involved in school health clinics, acted as referral agents, or provided screening or treatment for youth using drugs.

McBride et al. (2008) conducted an investigation of the role for PHUs in the provision of resources or education to address youth substance use as well as its role in advocacy for policy change.[3] After surveying a nationally representative sample of youth, they found that 56% of respondents lived in an area where the local public health agency provided financial or human resources for the prevention of illegal drug use, and 35% of respondents lived in an area where the local PHU provided education in school health clinics on substance use prevention.[3] 24% and 35% of respondents had their local PHU involved in advocacy for needle-exchange programs or alternatives to jail sentences for illicit drug use, respectively. Analyzing racial distribution as a predictor of PHU engagement, McBride et al. (2008) found that there were more respondents reporting PHU engagement in school health clinics from sites with above-average proportions of African Americans than sites with below-average proportions of African Americans. When controlling for the size of the White population, respondents living in sites with Hispanic populations larger than the national average were less likely than those in sites with smaller than average Hispanic populations, to have their local PHU providing education in school health

clinics on substance use prevention. Thus, VanderWaal et al. (2006) and McBride et al. (2008) both find that community racial composition is a predictor of the likelihood of PHU engagement in school-level substance use prevention.

Vermeer et al. (2021) studied the association between PHU engagement and numerous aspects of adolescent health and health behaviours, including depression, anxiety, physical activity, nutrition, screen time, substance use, bullying, and sedentary behaviour.[1] PHU engagement was categorized as: no engagement; provision of information/resources/ programs; problem-solving jointly with schools; or developing/implementing program activities jointly with schools. Vermeer et al. (2021) found that adolescents who had exposure to PHU provision of information/resources/programs to address sedentary behaviors had lower odds of meeting the guidelines for screen time. Adolescents who had exposure to PHU joint problem solving had higher odds of having better mental health, higher odds of meeting the guidelines for screen time, and lower odds of bullying others. Developing/implementing program activities jointly was not associated with any health outcome. No category of PHU engagement was associated with substance use.

Burnett et al. (2022) conducted a similar study, though with a focus on substance use outcomes alone.[2] They found no association between PHU engagement and substance use, where engagement was categorized as any form of PHU collaboration in schools compared to no collaboration. However, after stratifying schools by higher-than-average or lower-than-average substance use and looking at different types of engagement, some associations were noteworthy. For example, in schools with below average substance use, PHU provision of information/resources/programs was associated with lower odds of binge drinking alcohol, and in schools with above average substance use, it was associated with lower cigarette use. In schools with below average substance use, joint problem solving was associated with a higher odds of alcohol use, and joint development/implementation of programs was associated with higher odds of cannabis use. According to these studies by Vermeer et al. (2021) and Burnett et al. (2022), the association between PHU engagement in schools and adolescent health depends on the method of engagement (e.g., resource provision vs. joint problem-solving) and varies for different health outcomes. These findings suggest that, even if an association may exist, there is no consistent directionality. Of note, because both these studies were cross-sectional and thus lacked temporality between exposure and outcome, it is not clear whether significant

associations between the hypothesized exposure and outcomes were causal. PHU engagement may have been a cause of health behaviour change among students, or it may have been a result of poor health behaviours that needed to be addressed.

Table 2.1. Summary of key findings from narrative review of public health unit (PHU) engagement in schools.

Author & Year	Location & Study Design	Study Objective(s)	Health Outcome(s)	Method of PHU Engagement	Relevant Findings/Outcomes
VanderWaal et al. (2006)	USA, 1999-2003 Cross-sectional	Examine the role of PHUs in providing access to adolescent drug treatment services in school health clinics, juvenile drug courts, and other community agencies	Youth substance use	**Capacity building:** Involvement in school health clinics to provide resources, assess substance use or treatment needs, provide drug screening or treatment, treatment referrals, resources for treatment, and counseling	• Likelihood of having exposure to public health agency involvement in school health clinics depended on type of involvement, region, and proportion of African American residents • Youth in communities with above average concentration of African American people more likely to have PHU involvement in schools
McBride et al. (2008)	USA 1999-2003 Descriptive	Examine local PHU involvement in advocacy for illicit drug policy related to youth; determine extent of PHU involvement in local drug policy activities	Youth substance use	**Capacity building:** PHU provision of financial or human resources for community- and school-based illicit drug use prevention; provision of drug use prevention education in school health clinics	• PHU participation in school health clinics was higher for youth in sites with above-average proportion of African-American residents • Majority of youth were in areas where PHU provided traditional services (e.g. drug abuse prevention) but fewer in areas where PHU was involved in implementing alternative drug policies • More youth were in areas where PHU was involved in alternative policy advocacy than where PHU participated in treatment-based alternatives to incarceration • Youth in urban areas more likely to have advocacy by PHU for needle-exchange

Table 2.1. Continued.

Author & Year	Location & Study Design	Study Objective(s)	Health Outcome(s)	Method of PHU Engagement	Relevant Findings/Outcomes
Cousins et al. (2011)	North Carolina, USA 2008-2009 Descriptive	Describe role of state health department in supporting local efforts toward preventing childhood obesity and overweight; examine outcomes, strengths, and barriers to success	Childhood obesity	**Capacity building, joint program implementation:** State level: funding, training, technical assistance for capacity building at local level Local level: partners in program implementation, as well as policy and environmental change	• Policy changes were made to support physical activity and healthy eating • New phys. ed. curriculum introduced • Discontinued funding was a barrier to sustainability • County coordinators were instrumental to program success through information sharing, problem solving, trouble shooting, facilitating data collection
Alleman et al. (2017)	DuPage County, Illinois, USA 2011-2015 Descriptive	Describe prevalence of childhood obesity and describe role of PHU in surveillance of childhood obesity	Childhood obesity	**Surveillance/data collection:** Surveillance system developed and maintained by PHU using secondary data from schools	• Obesity prevalence in DuPage County public schools lower than national average • Rate among males was higher than average, rate among females was lower than average; kindergarten obesity rate higher than average
Cottrell et al. (2017)	Ohio, USA 2009-2012 Descriptive/ Case study	Describe a partnership between University research center, local PHU, and local school system in addressing school health	Fitness/ physical activity	**Surveillance/data collection** and **capacity building:** Community planning and staffing, intervention programming	• Partnership allowed for research in schools: found association between fitness and standardized test scores, • School-specific evidence informed intervention planning, and prompted ongoing research • Interests, needs, goals of all partners were taken into consideration

Table 2.1. Continued.

Author & Year	Location & Study Design	Study Objective(s)	Health Outcome(s)	Method of PHU Engagement	Relevant Findings/Outcomes
McCann et al. (2021)	Duval County, Florida, USA 2014-2018 Descriptive	Describe 5-year project to provide sexual health services (SHS) through School Based Health Centres; Document community support for this initiative	Sexual health: sexual health education, sexually transmitted disease testing, teen pregnancy	**Capacity building:** Partnership facilitated improved processes, policies, laws, protocols; partnership allowed PHU to share expertise and resources for SHS	• Successful implementation of school-based SHS for at-risk youth, recruitment of youth to attend educational sessions and receive testing and treatment; partnership considered important to success
Vermeer et al. (2021)	Ontario, Canada 2017-2018 Cross-sectional	Examine barriers to improving student health in schools; Analyze extent and effect of PHU engagement on student health behaviours	Screen time, mental health, bullying, physical activity, sedentary behaviour, and substance use	**Capacity building** through provision of resources, **developing/implementing programs jointly**, or **solving problems jointly**	• Majority of schools receive resources from PHU, less than 30% develop/implement programs jointly, and 12% report no engagement • Lack of consistent PHU engagement • Stronger partnerships may alleviate some barriers to implementing health interventions
Auger et al. (2022)	Cincinnati, Ohio, USA 2020-2021 Descriptive	Describe a partnership between local PHU, children's hospital, and school district, to design, implement and test COVID-19 mitigation strategies	COVID-19: cases, tests, time from feeling unwell to isolation	**Surveillance/data collection** and **capacity building:** Plan, design, implementation of covid mitigation program; positive tests reported to PHU; close contact identification & notification by PHU staff	• Schools able to continue operation thanks to quick identification and isolation of COVID-19 cases, case reporting, tracking of contacts and program improvement through daily huddles and reflection

Table 2.1. Continued.

Author & Year	Location & Study Design	Study Objective(s)	Health Outcome(s)	Method of PHU Engagement	Relevant Findings/Outcomes
Bejster et al. (2022)	Lake County, Illinois, USA 2016/17-2019/20 Descriptive	Describe a partnership between county PHU and local school district to address childhood obesity	Childhood obesity	**Capacity building**: support, guidance in needs assessment, program development, implementation and evaluation; financial support, materials, etc; resource and knowledge sharing	• Positive program outcomes: increased teacher knowledge and confidence and increased parental knowledge regarding healthy childhood behaviours • Learned importance of resource sharing and building a stronger program with mutual partner benefits • Increased community capacity to promote health
Burnett et al. (2022)	Ontario, British Columbia, and Alberta, Canada 2018-2019 Cross-sectional	Determine the impact of PHU engagement in school-based substance use prevention programs on student substance use	Substance use: alcohol, cannabis, cigarette, and e-cigarette use	**Capacity building** through provision of resources, **developing/implementing programs jointly**, or **solving problems jointly**	• No association between overall PHU engagement and any substance use • Joint problem solving associated with higher odds of binge drinking, alcohol use, cannabis use • Associations differed when looking at high and low use schools separately: for example, in low use schools, PHU provision of resources/information/programs was associated with lower binge drinking but joint problem solving was associated with higher binge drinking

Table 2.1. Continued.

Author & Year	Location & Study Design	Study Objective(s)	Health Outcome(s)	Method of PHU Engagement	Relevant Findings/Outcomes
Kiernan et al. (2022)	California, USA 2020 Descriptive	Report on evaluation virtual training to build the knowledge and confidence of School Specialists in protecting student health and reducing learning achievement gap during COVID-19 pandemic	COVID-19	**Capacity building:** Local Health Department: COVID-19 guidance, case/outbreak investigation, data management; consultation with university and state health department who were designing the training program; State Health Department: provide virtual training	• School Specialist training effective in increasing knowledge and confidence of trainees
Kunz et al. (2022)	McHenry County, Illinois, USA 2020 Descriptive	Describe a multidisciplinary collaboration for healthy student outcomes in the context of the COVID-19 pandemic, for best practice strategies to prevent illness and disseminate COVID-19 relevant information	COVID-19	**Surveillance/data collection** and **capacity building:** Public health nurse collaboration with school nurse to form School Nurse Task Force in: surveillance, health promotion, outbreak investigation, information dissemination to stakeholders, contact tracing, and team meetings for ongoing reflection & evaluation of public health activities	• School Nurse Task Force was established • COVID-19 toolkit was developed • Ongoing operation of school was made possible during COVID-19 pandemic

2.3 Public health unit organization in three Canadian provinces

This thesis will focus specifically on PHU collaboration with schools in the Canadian provinces of Ontario, Alberta, and British Columbia (B.C.). In each of Ontario, Alberta and B.C., one or multiple public health authorities are responsible for designing and delivering public health programs and services in their respective jurisdictions. However, the number of public health authorities and the organization of each public health system varies across provinces. Below is a brief overview of the organization of public health in each province, along with the role that public health plays in schools – including their work in substance use prevention. Of note, public health involvement in schools is guided by the Comprehensive School Health (CSH) model. CSH will be discussed further in section 2.3.4 of this chapter. Briefly, CSH aims to build healthy school communities by addressing risk factors for poor health and strengthening the physical, social, and community environments in which students live, study, and play. In other words, the CSH model calls for comprehensively addressing multiple social determinants of health.

2.3.1 Ontario

As of 2023, there are 34 local public health units in Ontario. This number was 36 in 2018 and 35 in 2019, as health units merged.[24] Public health in Ontario has a decentralized structure, in comparison to Alberta or British Columbia, which have fewer and larger regional health authorities.[20,24] Each public health unit in Ontario is managed by a board of health and must operate in alignment with Ontario's Public Health Standards.[22] There are nine program standards, including Healthy Environments, Immunization, Food Safety and School Health. There are also four foundational standards: Population Health Assessment, Health Equity, Effective Public Health Practice, and Emergency Management. The foundational standards outline goals and requirements for each program standard. These standards were set by the Ministry of Health and Long-Term Care (MOHLTC), to which all boards of health are accountable (note that as of 2019, the MOHLTC has separated into the Ministry of Health and the Ministry of Long-Term Care). Where PHU jurisdictional boundaries overlap with First Nations communities, First Nations may have written agreements with the local PHU regarding the delivery of public health programs and services.[20] It is a requirement within the Health Equity standard for PHUs to foster meaningful and collaborative partnerships with First Nations

communities and organizations. Public health services for on-reserve First Nations are typically a responsibility of the federal government or local community health centres.[25]

The school health standard aims "to achieve optimal health of school aged children and youth through partnership and collaboration with school boards and schools."[22] Substance use prevention and harm reduction is one area for which PHUs may offer support to schools, and intervention programs in this area must be implemented following the most up to date *Substance Use Prevention and Harm Reduction Guideline,* as written by the Ontario Ministry of Health. Whether PHUs support schools in the area of adolescent substance use, and how they do so, varies by jurisdiction and by school needs. Public health nurses are key players in bringing public health to the school community. They are part of multidisciplinary teams working to holistically and comprehensively promote the health of children and youth.[26] The Community Health Nurses Initiatives Group interviewed a sample of PHUs and found that eight of thirteen had assigned public health nurses to all schools, while three PHUs had assigned public health nurses only to specific, priority schools.[26] Other PHU staff who may be assigned to work with school boards include PHU managers, health promoters, or designated school health directors. PHUs may also be involved with schools through the Ontario Healthy Schools Coalition. This is a multidisciplinary team with a mission to improve the health and learning of children and youth in Ontario by promoting healthy physical and social environments for students and ensuring their access to knowledge, resources, and services.[27] Members of the Ontario Healthy Schools Coalition include public health units, school boards, academic institutions, hospitals, parent and student organizations and others.

2.3.2 Alberta

In Alberta, public health programs and services are primarily the responsibility of Alberta Health Services (AHS), a provincial health authority that is accountable to the AHS Official Administrator, who themselves are accountable to the province's Minister of Health.[96] In contrast to Ontario's independently operating health units, Alberta's health authority is a single, integrated system across five regional zones: North Zone, Edmonton Zone, Calgary Zone, Central Zone and South Zone. Whereas public health unit services are distinct from medical services in Ontario's public health system, AHS covers both medical care and public health. Within AHS, public health services are part of the provincial "Population and Public Health"

program and the Population and Public Health Strategic Clinical Network. AHS's strategic clinical networks are teams of professionals with expertise in a specific area of health who work collaboratively to develop innovative solutions, advance care, and improve outcomes for all Albertans.[29,30] The Population and Public Health Strategic Clinical Network includes health care workers, researchers, and educators working to promote and protect health and health equity.[29,31,32] This work is guided by a Population and Public Health Core Committee as well as an Indigenous Health Core Committee, both including experts from academia, government, professional associations, and non-profit organizations. Public health services for Indigenous communities in Alberta are specifically guided by the Indigenous Wellness Core.[30] This is a province-wide, culturally sensitive program that aims to improve and support primary health care for Alberta's Indigenous communities, but also supports health promotion and preventative care through partnerships with Indigenous communities and Indigenous decision-makers.[30] Public health programs and services also exist at the zone level, in coordination with the provincial Population and Public Health program. Public health services at the zone level are offered by AHS Community Health Centres.[33]

In school settings, AHS has a School Health & Wellness Promotion team that plans and coordinates initiatives to improve nutrition, active living, and mental health in children and youth 6 to 18 years of age.[34] The team includes health promotion facilitators who perform or support health assessment, action planning, and the development and implementation of healthy school policies. AHS also offers expertise and resources to schools through the Healthier Together – Schools initiative, using the comprehensive school health model.[5,35] Healthier Together is an initiative of AHS and the Government of Alberta to create an interactive website of tools and resources for health promotion in communities, workplaces, healthcare settings, and schools. Through Healthier Together – Schools, AHS also offers public health inspection services (for outbreak prevention and control, water safety testing, indoor air quality monitoring, etc.), school health nursing services (e.g. immunization education and administration, resources for parents, referrals), and general health promotion services.[35] To target substance use directly, AHS provides educational resources on addictions and mental health to schools, as well as a toolkit for peer leadership programs addressing substance use.[36]

2.3.3 British Columbia

In British Columbia, both medical services as well as public health programs and services are provided by five regional health authorities alongside the Provincial Health Services Authority. One of the agencies run at the provincial level is the B.C. Centre for Disease Control.[37] It provides programming, services, clinics and data tools to address a wide range of public health issues. The regional health authorities are Fraser Health, Northern Health, Vancouver Coastal Health, Interior Health, and Vancouver Island Health. Similar to Ontario's public health units and Alberta's centralized health authority, each B.C. health authority is accountable to a board of directors and to the Minister of Health. The regional health authorities operate independently, but in collaboration with the Provincial Health Services Authority as part of a network that provides core public health programs province-wide.[38] These core programs, as per the B.C. Guiding Framework for Public Health, are in the areas of maternal, child and family health, mental health and substance-related harms, and environmental health, among others. Each health authority also collaborates with the provincial First Nations Health Authority to promote health in B.C.'s Indigenous populations. Within the Ministry of Health, the Office of Indigenous Health collaborates with the First Nations Health Authority, regional health authorities, and provincial health authority, as well as other Indigenous partners to bring an Indigenous perspective to legislation, policy and program development.[39] At a more local level, program and service delivery occurs within local health units as well as community-based organizations that may receive funding from regional health authorities.

Importantly, public health collaborates with different sectors of government, community-based organizations, academia, schools, workplaces and non-profits. Similar to Ontario and Alberta, public health collaborates with the education sector within the comprehensive school health framework, in the form of its Healthy Schools B.C. initiative.[40] Healthy Schools B.C. is a partnership between the ministries of Health and Education, the registered charity Dedicated Action for School Health (DASH) B.C., regional health authorities, and others.[40] Schools are identified as partners in achieving multiple goals of the B.C. Guiding Framework for Public Health, including Positive Mental Health & Prevention of Substance Harms.[41] One performance indicator, toward the goal of achieving healthy living and healthy communities, is "the percentage of students in grades 3, 4, 7, 10 and 12 who report they are learning how to stay healthy." In order to achieve this goal, school-based healthy living programs exist on topics like

healthy eating, physical activity and avoiding tobacco use. Another way that substance use is addressed is through Integrated Child & Youth Teams working with school districts across the province.[42] These are multidisciplinary teams that improve accessibility of mental health and substance use services by offering services to adolescents right in their school and community.

2.3.4 Comprehensive School Health

Common to Ontario, Alberta and B.C., is the internationally utilized Comprehensive School Health (CSH) framework.[43] Developed from the Ottawa Charter for Health Promotion (1986), CSH is a framework that accounts for the interdependence of children's health and educational outcomes. Health can impact learning and educational outcomes are in turn associated with health and well-being into adulthood.[5,44,45] The Pan-Canadian Joint Consortium for School Health (JCSH) applies CSH in a Canadian context. Established in 2005, the JCSH is an agreement between provincial, territorial and federal governments, and a partnership between education and health systems, to support the health, well-being and learning of Canadian children and youth.[11,40,43,46] The CSH framework focuses on four key areas 1) the social and physical environment 2) teaching and learning 3) policy and 4) partnerships and services.[43,45,46] School partnerships can involve students' families, community organizations, health sector representatives, and other schools. Public health units can serve as one of those community partners, and may even help shape the social, physical and policy environments to address multiple areas of health and well-being.[3,9,43,47]

2.4 Conclusion

PHU collaboration with schools may be beneficial in addressing a variety of health outcomes, including childhood obesity, sexual health, infectious diseases, physical activity and substance use. Collaboration between PHUs and schools may allow for school-level data collection on health outcomes, capacity building through the provision of financial and human resources and consultation, delivery of health promotion programs and services, and joint problem solving. Importantly, schools are a setting where students of all socioeconomic statuses or racial/ethnic backgrounds can be efficiently reached. In the context of social inequities that result in health disparities, the school setting offers increased accessibility and opportunity to serve students in greatest need or at highest risk of poor health outcomes.[55]

2.5 Background: Public health spending and population health outcomes

Spending by public health units is a second indicator of interest in studying the role of PHUs in addressing adolescent substance use. The association between public health spending and population health has been studied for various health outcomes, and in various settings. In defining public health spending, "public health" is described by Acheson (1988) as "the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society".[48] Public health spending is thus distinct from spending on medical or hospital care that is treatment-oriented rather than preventive. "Public health spending" in this thesis will refer to expenditure for preventive public health programs and services including, but not limited to, spending on tobacco and alcohol control, food and water safety, immunization and control of infectious disease, and promotion of mental and sexual health. Because of the significance of social factors on population health, spending on public health may be studied in combination with spending on social services, which is indeed the case for some previous research.[49–52] In this thesis, public health spending will specifically refer to per capita expenditure by local level public health units, and will not include public health expenditure by provincial/state/federal governments.

Singh (2014) completed a systematic review of the association between public health spending and health outcomes, with a focus on research completed in the United States between 1985 and 2012.[53] All studies on public health spending and population health outcomes described analyses of public health spending either at the level of local health departments or at the state level, after aggregating local level data. There was a mix of cross-sectional and longitudinal quantitative studies, along with one qualitative case study. The case study discussed organizational efforts to align federal and state level financing for immunization service delivery with local service delivery needs. Among the quantitative studies, health outcomes included teenage birth rates and receipt of prenatal care among mothers under twenty, immunization rates among children, and infant mortality rates. Other health outcomes studied in the general population included all-cause or cause-specific mortality, county health rankings, smoking and obesity prevalence estimates, infectious disease morbidity, and premature death. The quantitative indicators of public health spending included total per capita public health expenditures by local health departments (LHD), program-specific expenditures by LHDs, locally generated tax dollars for health care, trends in LHD funding, percentage of public revenue allocated to LHDs, LHD

expenditures aggregated to the state level, and the utilization of property tax levies to fund local public health.

In this review, nine of ten studies looking at public health spending report a beneficial association between spending on public health and various health outcomes of interest.[53] Becker et al. (1998) found that higher expenditures on maternal and child health were associated with a lower percentage of teen births and a lower percentage of infants whose mothers did not receive adequate prenatal care.[54] Similarly, Bekemeier and colleagues found an association between the provision of maternal and child health services and lower mortality rates - though the association varied by the type of service and age or gender group studied.[55] Grembowski et al. (2010) found some evidence that increases in LHD expenditure was associated with reduced mortality rates, but only among specific groups, including infants, Black populations, and White females.[56] Mays and Smith (2011), looking at cause-specific mortality, found that a 10% increase in LHD expenditure was associated with a decline in infant mortality and mortality related to cardiovascular disease, diabetes and cancer.[57] Erwin and colleagues found that higher LHD spending was associated with reduced infectious disease-related morbidity and premature death.[58,59] Findings of the case study on LHD organizational factors did not report on public health spending, but did find a relationship between financing decisions and the needs and challenges related to childhood immunization coverage.[60] Only one study reported a consistently inverse association between public health spending and population health.[61] Boeke et al. (2008) found that increased LHD expenditure was associated with lower rankings on county health outcomes.

Two authors report inconsistent evidence on public health spending and the impact on disparities in mortality between Black and White racial groups.[53,55,56] Grembowski et al. (2010) found that increased LHD expenditures were associated with a reduced racial disparity in mortality rates, but only among adults aged 15-44.[56] Bekemeier et al. (2012) found that, in the context of maternal and child health services, spending on family planning and prenatal care, but not other services such as obstetric care, was associated with reduced racial disparities in mortality.[55] Conversely, increased expenditure on obstetric care was associated with increased health disparities among females, by race. Nevertheless, these findings suggest public health spending may be associated not only with improved population health, but also reduced health inequities.

Since Singh's review, there has been increasing research in the area of public health investment and population health. In the US, a study from 2004-2013 on infant and neonatal health found that increased federal funding to the state level was associated with lower infant mortality, neonatal mortality, and post-neonatal mortality rates.[62] Williams and colleagues (2019) reported that increased federal funds from the CDC to states were associated with lower cumulative rates of chlamydia and gonorrhea – 0.17% and 0.33% respectively, for a 1% increase in annual funding.[63] Martin et al. (2020) studied the cross sectional association between national public health grants to local authorities, and quality-adjusted life years in the UK (2013-2015).[64] They report one quality-adjusted life year as costing 3,800 pounds of the local public health budget, as compared to 13,500 pounds of the healthcare budget. This suggests a greater economic advantage of prevention-oriented spending as compared to treatment-oriented spending.

2.6 Narrative review: Public health spending and population health outcomes

To update the systematic review by Singh (2014), a literature search was conducted for studies published in the ten years from 2013 to February 2023. The search terms used were ""Public health" or government* or municipal* or provinc* or state* or federal* or territor* or "health unit*" or "health authorit*" or public or county or counties" combined using the AND operator with "expenditure* or spending* or investment* or divestment* or fund* or financ* or budget* or expense*" AND ""Community health" or "public health" or "population health."" This search was conducted in databases PsycINFO, Medline, CINAHL, PAIS, and Web of Science. The search resulted in over 6000 results. To further narrow search results during title and abstract review, only studies on local public health unit expenditure and population health outcomes were included. Studies were excluded if they only described funding *for* public health units rather than the amount spent, or if they only described the amount spent by state/provincial/federal public health rather than local-level public health units. There were fourteen studies published since Singh's review that met the inclusion criteria. A summary of findings is shown in Table 2.2.

Twelve of fourteen studies took place in the United States, while the remaining two took place in England. All were ecological analyses of area level spending and area level health outcome data. Health outcomes investigated were under-18 conception rate, rate of low birth

weight, child overweight or obesity, incidence of communicable diseases (enteric disease, COVID-19, sexually transmitted diseases gonorrhea and syphilis, and pertussis), immunization coverage, incidence of non-communicable diseases (cancer, heart disease, diabetes, and asthma), overall county health rankings, and mortality. Specifically, measures of mortality included infant mortality, maternal mortality, all-cause mortality, and cause-specific mortality (related to heart disease, diabetes, cancer, asthma, pneumonia and influenza). The quantitative indicators of public health spending included per capita public health expenditures by local health departments (LHD), program-specific expenditures (pregnancy services, immunization, childhood obesity, physical activity, food safety and sanitation), total non-hospital health spending (sum of public health, public clinics, behavioural health, and disability-related clinical care), and relative allocation of expenditures for community and public health. Evidence on the association between public health spending and health outcomes is mixed. Seven of these fourteen studies report a beneficial association between local level public health spending and population health, three studies report no association, one study finds increased spending to be associated with poor health outcomes, and three studies report mixed results. Of those reporting a beneficial association or mixed findings, nine are longitudinal studies and one, by McCullough and Leider (2017), is cross sectional. There is variability in the definition of public health spending whereby seven studies measure total per capita spending, four measure program-specific per capita spending, and three measure both.

Bekemeier et al. (2014) found that higher PHU spending was not associated with rates of low birth weight overall, but there was a significant association found after stratifying by youth poverty level.[65] Higher PHU spending, whether it was total spending or maternal and child health program-specific, was associated with lower rates of low birth weight in counties with the highest percent of children (<18 years) in poverty. Higher total PHU spending was also associated with lower infant mortality rates in counties of high poverty. Bernet et al. (2018) did not find total per capita spending to be associated with infant mortality, but a 10% increase in spending on infant-related programs specifically, was associated with a 2% decrease in infant mortality overall.[66] Similar to Bekemeier et al. (2012) and Grembowski et al. (2010), Bernet and colleagues (2018) stratified their model by race. They found that, although there was a null association among White infants, a 10% increase in spending was associated with a 4% decline in infant mortality among Black infants. These findings provide evidence not only for improved

health outcomes with increased public health spending, but also a reduction in health disparities based on poverty or race.[65,66] These results are consistent with findings by Bekemeier et al. (2012), but in contrast to Grembowski et al. (2010), who did not find a reduction in Black-White mortality differences with increased spending, except among 15-44 year olds.[55,56] Bernet and colleagues (2020) found that maternal mortality decreased by almost 4% with a 10% increase in spending on maternal and child health programs.[67] Similar to Bekemeier et al. (2012) and Bernet et al. (2018), they found that increased program-specific spending was associated with reduced health disparities. There was a null association found among White mothers, but among Black mothers, a 10% increase in targeted programs was associated with a 13.5% decline in maternal mortality.[67]

Brown (2014) studied overall, all-cause mortality and found a protective effect of per capita public health spending at the county level. According to their results, a $10 increase in per capita spending was associated with a decline in mortality by approximately 9 deaths per 100,000 - specifically when looking at the long-term (approximately 8 years following the spending exposure). There was also a protective effect in the short term of one year, but it was smaller in size, with just under 3 deaths per 100,000 prevented.[68] A strength of all four of these studies (Bekemeier et al. 2014, Brown (2014), Bernet et al. (2018 and 2020)) is that they were longitudinal, allowing for temporality to be established between spending and mortality. They also accounted for endogeneity, whereby spending may be influenced by another variable of interest within the same model, such as health outcome trends. Contrary to these results, a study by Schenck et al. (2015) found no association between per capita local health department spending and heart disease, cancer, diabetes, pneumonia, influenza, nor infant mortality rates.[69] Schenck et al. (2015) studied exposure and outcome before and after a specified time point (2008 economic recession). They were unable to account for endogenous ecological variables. Although they found no association between total spending and health outcomes, they did find evidence for reduced infant mortality with increased investment in PHU staffing and services.

Some researchers have focused on the impact of public health spending on communicable diseases, but with mixed evidence of a protective effect.[70–72] Studying local health departments in New York and Washington states from 2000-2010, Bekemeier and colleagues (2015) found that a $1 increase in local health department spending on food safety and sanitation was associated with 0.09 fewer cases of cryptosporidiosis per 10,000 person-years and 0.05 fewer

cases of salmonellosis per 10,000 person-years, in New York and Washington respectively.[71] In the same timeframe and setting, with the addition of Florida, Bekemeier and colleagues (2017) studied immunization coverage among toddlers, and pertussis incidence per 100,000 population over 11 years.[72] Similar to Bekemeier et al. (2015), they looked at program-specific spending but found no association between local health department immunization-related spending and immunization coverage nor between spending and pertussis incidence. Lamba and colleagues (2022) studied the association between per capita non-hospital spending in 2015 through 2017 – prior to COVID-19 – and two COVID-19-related outcomes in 2019 and 2020: time to peak incidence and case doubling time, locally.[70] Similar to Bekemeier et al. (2017), they found no association, though unlike Bekemeier and colleagues (2015, 2017), they studied total spending rather than program-specific spending. Differently from the studies discussed thus far, Lamba et al. (2022) did not look at public health unit spending alone, but rather all public health, public clinic, behavioural health, and disability-related clinical care spending, including non-PHU spending – all at a local, county level. All three studies accounted for temporality between spending and the health outcomes of interest, with health outcome measures following spending measures. A limitation of all three of these studies is that none accounted for endogenous ecological variables that may have impacted the level of public health spending.

Other authors have studied spending and teenage pregnancy or sexual health. Paton and Wright (2017) investigated expenditure related to teenage pregnancy services by local authorities in England, and under-18 conception rate from 2009-2014.[73] Contrary to the majority of studies discussed so far, they found that less public health spending was associated with better health outcomes, whereby a 10% reduction in spending on teen pregnancy services was associated with a 0.25% reduction in conception rate, 0.19% reduction in abortion rate, and 0.32% reduction in birth rate among teens. Gallet (2017) conducted a study of counties in California, US, investigating total public health spending per capita, rather than spending specific to any one service, and how it was related to rates of gonorrhea and syphilis.[74] They found that from 2003-2012, a $1 increase in public health spending was associated with a 0.3% and 0.6% decline in gonorrhea and syphilis rates respectively. Unlike other studies described here, Gallet (2017) also accounted for public health spending by nearby counties in case of "spillover effects" on a given county of interest. The differing findings by Paton and Wright (2017) compared to Gallet (2017) may be due to a number of factors, including the differing locations (Europe vs the US), the

differing outcomes of interest (pregnancy outcomes vs STDs), or differing exposure (program-specific spending vs total public health spending). Both studies demonstrated temporality between spending and the health outcomes of interest and both accounted for endogeneity.

In England, Liu and colleagues (2019) compared local authority expenditure on health programs targeting children 5-19 with child obesity rates three years later.[75] They reported mixed results. Although total spending and obesity rates were not associated, increased spending on physical activity was associated with less obesity in children aged 4-5 when spending was analyzed as a categorical variable. As a continuous variable, increased spending on physical activity was associated with less obesity in children aged 10-11. These results are consistent with other studies that find a beneficial association between program-specific spending and population health and/or no association between total spending and population health,[67,69–71] but inconsistent with studies that find no association or an inverse association between program-specific spending and population health.[72,73]

McCullough & Leider (2016 and 2017) studied local public health spending and county health rankings. Like Lamba et al. (2022), they defined public health spending as all public spending on community or public health activities, rather than spending primarily by PHUs. In a cross-sectional analysis, the authors found that an increase in total public health spending was associated with higher county health rankings.[76] Taking a longitudinal approach, they similarly found an association between higher social spending, including community health care and public health spending, and improved county health rankings.[77] Additionally, they found that median per capita expenditure was higher for those counties in the top three quartiles of health rankings, as compared to counties in the lowest quartile of health rankings. Finally, Brown and colleagues (2014) conducted a longitudinal study that also demonstrated a beneficial impact of public health spending.[78] According to their findings, a $100 increase in per capita PHU spending was associated with a 0.65% increase in the percentage of the population reporting good, very good, or excellent health. These latter two studies, with a five-year study period or longer, lend support for an association between public health spending now and improved population health in the future.

Though more research is needed, there has been some investigation of the pathways by which an association between public health spending and health outcomes might occur. In their systematic review, Singh (2014) found that a common hypothesis in the literature is that

organizational capacity may explain this association.[53] Specifically, improved organizational capacity can improve public health system performance, which may then allow for improved population health outcomes. In this proposed pathway, public health spending may be considered an indicator of financial resources, which are a component of organizational capacity. Public health system performance is reflected by the internal processes and human resources of a public health department that are required to implement disease prevention and health promotion activities.[53,70]There is mixed evidence, however, that public health system performance is associated with population health. As described in the review by Singh (2014), increased funding for public health does not guarantee improved performance of a public health organization, nor does its improved performance guarantee better health outcomes. Thus, there is greater research needed on the pathway between public health spending and health outcomes to understand the nuances of each component in the proposed pathway.

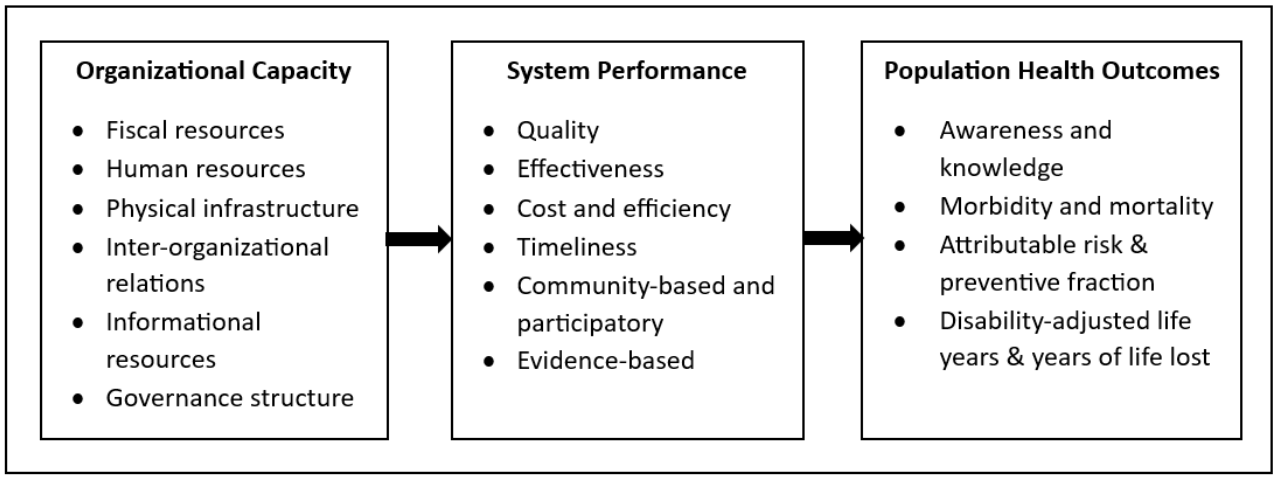

Figure 2.1. Conceptual model for association between public health spending and population health outcomes, simplified and adapted from Meyer et al. (2012).

Table 2.2. Summary of findings from narrative review on local public health spending and population health outcomes.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Brown (2014)	Ecological, longitudinal 56 counties in California, USA 2001-2008	Dynamic panel model; approximate the lag structure using the Koyck distributed lag model	Total county level public health spending, per capita	All-cause mortality per 100,000 population	Proportion of population with: Medicaid, Medicare, and private health insurance; proportion of population under age 15, over age 85, and in each ten-year interval in between); proportion that is Hispanic, Black, Asian/Pacific Islander, Other Race; relative per capita income, unemployment rate, crime index, high school completion per 100,000, population density	• Public health spending causally related to mortality reduction - average long run effects 3.37 times the size of average short run effect • An additional $10 per capita public health spending associated with reduction in all-cause mortality by 9.1 deaths per 100,000 deaths in the long run (2.7 in the short term). • In the long run, annual number of lives saved by the presence of county departments of public health in California is estimated to be approximately 27,000 (26,937 lives, 95% CI: 11,963, 41,911)
Brown et al. (2014)	Ecological, longitudinal 40 counties in California, USA 2001-2009	Dynamic panel estimation techniques; Lewbel instrumental variable technique; standard Koyck distributed lag model	Total county level public health spending, per capita	County-level general health status, by self-rated health	Proportion of population covered by health insurance, per capita income; population age categories (proportion in each category), proportion of population with a bachelor's degree or higher; proportion of individuals in each racial group (White, Black, Hispanic, Asian/Pacific Islander, Other)	• A $10 increase in per capita public health spending is associated with an increase in the percentage of the population reporting good, very good, or excellent health by 0.065%

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Bekemeier et al. (2014)	Ecological, longitudinal 102 local health department (LHD) jurisdictions 2000-2010	Multivariate panel time-series with stratification by county-level poverty	Per capita LHD expenditure: total expenditure as well as service-specific expenditure in the area of maternal and child health (MCH)	County-level rates of low birth weight and infant mortality	LHD level: presence of an alternative provider of MCH services, clinician as LHD top executive; Community level: Socioeconomic Disadvantage Index, percent Black, percent Hispanic, percent completed high school; urbanicity Health system level: per capita no. of physicians, percent county-wide Medicaid-funded births, total births	• Higher LHD expenditure, total or MCH-specific, was associated with fewer rates of low birth weight in counties of high poverty • Higher total LHD expenditure was associated with lower infant mortality rates in counties of high poverty • Higher total LHD expenditure was associated with lower infant mortality rates overall

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Bekemeier et al. (2015)	Ecological, longitudinal 72 local health departments in Washington and New York 2000-2010	Multivariate panel time-series using panel data	LHD food safety and sanitation expenditure	Incidence rates of enteric diseases (7 most commonly notifiable in New York and Washington), per 10,000 people	Social disadvantage index (constructed from median household income, proportion of households receiving public assistance, and unemployment rate); proportion of foreign-born residents and children 0-4 years; number of per capita food and drink establishments; rurality, state, year	• In New York, significant association between food safety and sanitation expenditure and cryptosporidiosis. When New York City controlled for, every $1 spent was associated with 0.091 fewer cases per 10,000 p-y, (0.083 if excluding New York City from model) • Significant association in Washington for salmonellosis: $1 spent associated with 0.053 fewer cases per 10,000 p-y. Significant association also for Washington + New York combined; No significant findings for other enteric diseases studied

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Schenck et al. (2015)	Ecological, longitudinal 83 local health departments in North Carolina, USA 2005-2010	Multilevel regression model; random intercepts for LHDs; aka 2 level random intercept model (LHDS and time)	Total LHD spending per capita; FTE per 1000 population	Age adjusted mortality rates (per 100,000) for heart disease, diabetes, cancer, pneumonia and influenza; also, infant mortality (per 1000 live births)	Percent female, percent 65 and older, percent non-White, percent non-English speakers; unemployment, percent college graduates, percent uninsured, percent in poverty; health care resources: number physicians per 100,000, public health clinics per 10,000 population, hospital beds per 100,000 population, total population, rurality	• No association between changes in spending and mortality • 1% increase in LHD FTE per 1000 population, associated with 0.01 fewer infant deaths per 1000 live births • Greater level of medical care treatment provided by LHDs associated with reduced infant mortality; no other association observed • Provision of prenatal care and obstetrical services associated with 1-2 fewer infant deaths per 1000 live births.

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
McCullough & Leider (2016)	Ecological, longitudinal 9,713 county-years in USA 2010-2015	Lagged random-intercept multivariate longitudinal models	Total spending by local government on various health and non-health services within a county, per capita	County health rankings	County health factors (social determinants and other factors related to the physical and social environment within a county), population, state and mean spending for each category of expenditure	• 7 areas of social spending have a modest, protective association with population health: community health care and public health, public hospitals, fire protection, K-12 education, corrections, libraries, and housing and community development • Median per capita expenditures were higher for counties in the top three quartiles of health factor rankings than counties in the bottom quartile • Counties in the top quartile tended to allocate a larger proportion of annual budget to community health care, public health, parks and recreation, among others

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Bekemeier et al. (2017)	Ecological, longitudinal 159 jurisdictions/ local health departments in Florida (67), New York (57), and Washington (35) 2000-2010	Multiple regression, stratified by level of poverty	Local health department immunization-related expenditures per capita (1 year, 2011, for completeness models as well as longitudinal, 11 years, 2000-2010, for pertussis rate model)	Toddler immunization completeness (1 year); annual jurisdiction-level numbers of pertussis cases per 100,000 population over 11 years	Total population size, rurality, percent Black residents, percent Hispanic residents, percent under age 5, percent older than age 65; Social disadvantage index (see Bekemeier et al 2015); whether or not local health department (LHD) is led by a clinician, whether or not an entity other than LHD providing childhood immunization services, LHD service delivery type; per capita rates of general practice physicians and nurse practitioners; state	• Immunization expenditures not associated with percent of toddler immunization completeness • Immunization expenditures did not have a longitudinal association with pertussis rates • Two covariates, percentage Black residents as well as social disadvantage, were associated with percent of toddler immunization completeness

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Gallet (2017)	Ecological, longitudinal 57 counties in California, USA 2003-2012	Multivariate panel data regression model; ordinary least squares as well as two-stage least squares; regression on instrumental variables	Total county level public health spending, per capita	Rates of gonorrhea and syphilis per 100,000	Average per capita public health spending by bordering counties; number of physicians per 1000 population; county unemployment rate; percent Black, Asian, Hispanic; percent aged 15-19, 20-24, 65+; presence of a university campus; instrumental variables: cancer mortality rate, heart disease mortality rate, foreclosure rate per 100,000; percent voters who are registered democrat	• $1 increase in per capita public health spending reduces the gonorrhea (syphilis) rate by roughly 0.30 (0.60) percent • Public health spending by neighbouring counties associated with reduced STD rates

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
McCullough & Leider (2017)	Ecological, cross sectional 3,141 counties in the USA 2012-2013	Multivariate logistic regression	Community wealth (median household income, percentage of families in poverty, median home value); Total county-level public spending on various expenditure categories including community health care and public health, parks and recreation, etc)	County health rankings	Spending estimates for community health care and public health, parks and recreation, public welfare, and other categories of social spending; county governmental spending and wealth, population size	• For each additional percentage point of total public spending allocated toward community health care and public health, the odds of being an overperforming (performing better on health outcomes than would be expected as per county wealth) county increased by 3.7% • Spending on public welfare, public hospitals, and solid waste management was also associated with being an overperforming county

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Paton & Wright (2017)	Ecological, longitudinal 149 local authorities in England 2009-2014	Fixed effects panel data regression model and instrumental variable regression	Annual local authority expenditure, per 13-17 year old female, on teenage pregnancy services	Under 18 conception rate	Education (aggregate), proportion 16-24 year old females unemployed; percent of children in workless households, percent of non-White students, rate of alcohol-related hospital admissions; proportion of children in government care; political party; local authority expenditure on all services for young people, as well as alcohol and drug prevention services specifically	• 10% reduction in expenditure associated with 0.25% decrease in under-18 conception rate, 0.19% decrease in abortion rate, and 0.32% decrease in birth rate • Socioeconomic factors found to be predictors of teen pregnancy
Bernet et al. (2018)	Ecological, longitudinal 67 counties in Florida, USA 2001-2014	Ordinary Least Squares Regression; Generalized Method of Moments	Total public health spending and targeted spending on infant-related programs	Infant mortality	Percent of population of that is child-bearing age (15-44), non-white, Hispanic origin, age 65 and older; additionally: unemployment rate, poverty rate, per capita income, Medicaid enrollment rates, availability of physicians and hospital beds	• No association between total public health spending and infant mortality • Differential impact by race: effect is non-significant for whites but significant for blacks • 10% increase in targeted spending per infant associated with 2.07% decrease in infant mortality ($p<0.05$) • 10% increase in targeted spending associated with 4.04% decrease in black infant mortality ($p<0.01$)

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Liu et al. (2019)	Ecological, longitudinal 150 local authorities in England 2013/14 to 2016/17	Random effects negative binomial models with panel data	Local authority (LA) per capita actual net current expenditure on (i) childhood obesity (ii) physical activity (iii) children 5-9 public health program (CPHP) (per capita from population aged 5-19 years only)	Proportion of children who are overweight or obese	Percent males in 4-5 age group and 10-11 age group; rurality; deprivation (percent population living in 20% most deprived small areas); ethnicity (percent primary school pupils who are not White); access to fast-food outlets (outlets per 100,000 population); type of local authority (unitary, metropolitan, shire, London boroughs)	• Levels of spending in 2013/14 was not significantly associated with level of childhood obesity in the short term (2016/17) in either age group (4-5 y.o. or 10-11 y.o.) • Exception: medium level of spending on childhood obesity or CPHP at baseline (2013/14) associated with higher level of childhood obesity in 2016/17 compared to authorities with low levels of spending for children 4-5 years old

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Bernet et al. (2020)	Ecological, longitudinal 67 counties in Florida, USA 2001-2014	Fixed-effects ordinary least squares regression and generalized method of moments models with panel data	Public health spending on pregnancy-related programs as a sum of spending on 1) maternal health and improved pregnancy outcomes 2) Healthy Start program, 3) Women, Infants, and Children nutrition program	Maternal deaths (female deaths due to complications during pregnancy, childbirth, or the period immediately following childbirth); expressed as deaths per 100,000 live births	Demographic, socioeconomic, macroeconomic, access to health care services: percent population non-White, Hispanic, of child-bearing ages (15-44), age 65+; unemployment rate, personal income per capita, percent births covered by Medicaid, number of physicians and hospital beds per 100,000 people	• 10% increase in targeted public health expenditures led to 3.9% decline in overall maternal mortality rates • Effect for white mothers was not statistically significant, but effect for black mothers was statistically significant: 10% increase in pregnancy-related public health spending associated with 13.5% decline in maternal mortality for black mothers, and 20% reduction in black-white maternal mortality gap

Table 2.2. Continued.

Author, Year	Design, Location, Timeframe	Statistical Method	Exposure and Jurisdiction	Outcome	Covariates	Key Findings
Lamba et al. (2022)	Ecological, longitudinal 2775 counties in the USA 2015-17 (spending data) to 2020 (outcome data)	Time to event and generalized linear models	Total non-hospital health spending (public health, public clinics, behavioural health, disability-related clinical care), per capita	COVID-19 case incidence (time to peak incidence and doubling time of case counts within the first 30 days of local epidemic)	Population density, COVID-19 testing rates per capita, percent Hispanic, percent Black, percent under 18, percent over 65, percent residing rurally, percent international migrants, percent domestic migrants, ratio of males to females; percent adults with at least college education, income inequality ratio, percent households that are food insecure, median household income, percent adults uninsured, active primary care physicians per 100,000 population, percent current smokers, percent obese, age adjusted death rate per 100,000; average temperature in March, April, and May; percent of 2020 presidential votes for Republicans	• County level non-hospital spending not associated with time to peak nor doubling time; significant associations found for state level spending

2.7 Public health spending and substance use

No published studies that explore an association between public health unit spending and substance use have been found in the literature. However, there has been research investigating spending toward the social determinants of health, and the impact on substance use. Friebel and colleagues (2021) published a study investigating the relationship between spending cuts by the UK government and opioid-related hospitalizations and mortality.[79] This study took place in the context of austerity measures taken in the UK following the 2008 economic crisis, when in 2010, the government disinvested from local authorities in various service areas. Net expenditure on social care, housing, and planning and development was the exposure of interest. They found that a £1,000,000 increase in total social expenditure was associated with decreases in opioid-related deaths by 0.017 per 100,000 and decreases in opioid-related admissions by 0.4 per 100,000 population. Higher social spending was also protective against the negative impact of unemployment rate on opioid-related deaths. A strength of this study is that temporality could be established through the use of panel data models.

Other researchers have looked at spending on particular public health programs rather than total public health spending, and the association with substance use. In a cross-sectional analysis, Gross and colleagues found that state spending on tobacco control was significantly lower for states with higher smoking rates.[80] Tauras and colleagues, in another cross-sectional analysis, found a statistically significant association between higher per capita expenditure for tobacco control and lower youth smoking prevalence as well as lower self-reported daily cigarette use.[81] The amount of spending, for most states, did not meet the suggestions provided by the national public health agency. However, modeling by Tauras et al. (2005) further suggests that, had state spending met these public health agency guidelines, youth smoking prevalence may have been 3.3% to 13.5% lower than it was. In the context of alcohol use, a study in Sweden showed that municipalities which received government support for alcohol prevention programs had more alcohol prevention policies and activities, and saw fewer indicators of alcohol-related harm.[82] These studies suggest that increased funding for substance use prevention may be related to improved substance use outcomes by way of program and policy implementation. It cannot be said whether this is generalizable to the funding and functioning of public health units, however it may be reasonable to expect a similar pattern given that PHUs have similar goals of preventing harmful substance use.

Researchers have also conducted economic evaluations of substance use prevention programs. White et al. (2018) conducted a systematic review of economic evaluations of local authority public health interventions and found that smoking cessation services were typically found to be cost-effective, although different studies reported different extents of cost-effectiveness dependent on the intervention and participant characteristics.[83] They found one study that reported significant cost-effectiveness of substance treatment interventions, though it did not include substance use prevention. The following year, Robertson et al. (2019) published a study examining five different public health programs in the UK: Drug and Alcohol Use, Health Checks, Smoke Stop, Sexual Health, and LiveWell Dorset.[84] They found the largest return on investment for the LiveWell Dorset program that aims to facilitate lifestyle changes by providing information, advice and support particularly in the areas of smoking cessation, reduced alcohol consumption, physical activity, and weight management. Investment in Drug and Alcohol Services, aiming to reduce dependency, had the second largest return on investment.

2.8 Conclusion

Whether we look at total or program-specific spending, there is evidence for the potential for increased public health spending to improve population health outcomes. Nevertheless, some studies also suggest a lack of, or an inverse association. There are limitations to consider when interpreting these findings. Though some authors did account for endogeneity in their analyses, not all authors did. As a result, it is possible that associations found between spending and health outcomes, beneficial or harmful, could have been confounded by other factors. For example, economic factors such as income inequality, recession, or austerity measures are known to have a negative effect on population health,[84–86] and may also limit financial resources available for public health units. Political factors such as conservative or neoliberal ideology can lead to policies that restrict public health services, such as access to abortion for people of reproductive age or access to harm reduction services for those who use substances.[3,73,79,87] Such policies may draw funding away from these public health services and result in poor health outcomes. Furthermore, spending by non-public health agencies on social services such as housing assistance, mental health services, parks and recreation, and other forms of social care are associated with improved health outcomes, but were not accounted for by most studies included in this review.[76,77,79] In the case of the cross-sectional study by McCullough and Leider (2017)

who do account for social spending, the lack of temporality still precludes any conclusion about causality, since spending decisions may have impacted health outcomes, or may have been a response to health needs.[76] Nevertheless, the majority of studies reviewed here allowed for the study of a temporal association between exposure and outcome and do lend support for a causal association. It is difficult to make any generalizations about the impact of spending on health outcomes, given that there are numerous different health outcomes discussed in the literature, and in different settings. It is possible that public health spending is a more important variable for some outcomes than others. This is especially true if organizational capacity is the pathway by which spending affects population health, and if some programs/services require more financial resources than others. However, it is also important to return to the socio-ecological framework and recognize that it is not merely the proximal determinants or targeted public health programs that impact health.[49,50,88] Health is influenced by numerous interacting factors across the socio-ecological model and public health spending overall may thus be an indicator of broader socioeconomic or political conditions that shape population health.

If it is true that public health spending improves population health, it may be beneficial in future research to investigate whether there is a threshold effect of spending. In other words, there may be a minimum amount necessary for a positive impact to be seen or a maximum amount may exist, beyond which increased spending may have marginal benefit. However, it is unlikely that any such absolute values exist, even if economic factors like currency and inflation are accounted for, due to the differences in programs and services across jurisdictions, differences in need, and differences in the cost of resources, etc. It may instead be useful to study whether there is an optimal proportion of public spending that can be directed toward public health for the best population outcomes. It would be important to consider the way in which population outcomes are defined. As demonstrated in this literature review, there are numerous indicators of population health and there may not be any one objective indicator to best reflect population health outcomes.

2.9 Literature Gaps and Research Objectives

This thesis addresses gaps in the literature on the association between PHU engagement and substance use. It is the first to adopt a longitudinal approach, exploring potential temporality in the association between PHU engagement at schools and adolescent substance use. While

Vermeer et al (2021) and Burnett et al (2021) used data from years 6 and 7 of the COMPASS study respectively, this study will use data from years 5 through 7 (2016-2019). The first objective of this thesis will be to investigate the association, over time, between PHU support for school-level substance use prevention programs and the use of alcohol, cannabis, cigarettes, and e-cigarettes among secondary school students.

Empirical evidence indicates that public health spending is a social determinant of health associated with population health outcomes. However, there is no previous research on the association between spending and substance use among adolescents. The second objective of this thesis is to investigate the association between per capita spending by public health units in Ontario and the use of alcohol, cannabis, cigarettes, and e-cigarettes among secondary school students.

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CHAPTER 3: PUBLIC HEALTH UNIT ENGAGEMENT IN SECONDARY SCHOOLS AND ADOLESCENT SUBSTANCE USE

3.1 Introduction

Adolescent substance use is a significant public health concern. In 2019, 46% of Canadian youth reported using alcohol in the past year and 22% reported using cannabis in the past year, while 5% reported using cigarettes, and 15% reported using electronic cigarettes (e-cigarettes) in the past month.[1,2] Compared to six years previously, adolescent alcohol and cigarette use declined, cannabis use stayed approximately the same, and e-cigarette use increased five-fold.[3]

Substance use during adolescence can have negative effects in the short and long term, potentially impacting developmental trajectories.[4–6] In the short term, adolescents may experience drug poisoning, respiratory problems in the case of cigarette or e-cigarette smoking, or impaired cognition as a result of alcohol or cannabis use.[7] Heavy substance use may negatively impact brain development in adolescents.[12–14] Substance use is also associated with high-risk behaviours such as distracted driving, aggression, unprotected sex or sexual victimization, and violence perpetration or violence victimization.[7–11] Depending on the type and frequency of substance use, long-term impacts can include substance use disorder, alcohol-related liver disease, and cancers related to cigarette smoking.

Various factors at the individual and interpersonal level are associated with adolescent substance use. There is evidence in the literature for a difference in substance use patterns between boys and girls.[15,16] Among students in grade 9-12, substance use is found to be higher in boys as compared to girls, and generally increases for those in higher grades.[16–19] Student race/ethnicity has also been found to be associated with substance use. For example, some studies have reported a lower likelihood of substance use among Asian or Black students as compared to White students.[16,17] Higher personal spending money has been found to be associated with more substance use.[17,20,21] Conversely, higher feelings of connectedness at school have been found to be protective against substance use.[19,21]

Public health aims to promote and protect health and implement primary prevention programs against poor health and illness. To address adolescent substance use, secondary schools are an ideal setting for action. Adolescents spend a large portion of their time in schools, making them relatively easy to reach for intervention activities. School-based substance use intervention

can involve: distributing educational materials (e.g. information on substances and substance-related harms); fostering skill development in resisting peer pressure and developing healthy coping strategies; fostering self-esteem and self-awareness; promoting mental wellbeing, and more.[22,23] While there is a significant amount of research on such programs and their effectiveness, there is little research on the role of public health units in these programs or in schools generally.

Studies on the role of public health units in schools describe surveillance and data collection activities to inform the development of school-based programs and policies, as well as capacity building by offering staff training programs, funding, or material resources.[24–28] Public health units can also take a more direct role by leading interventions in schools, or by engaging in problem-solving and program implementation together with school staff.[26,29] Two studies were conducted in Canadian provinces to explore the association between PHUs characteristics and adolescent health, both using data from the Cannabis, Obesity, Mental Health, Physical activity, Alcohol, Smoking, Sedentary behaviour (COMPASS) study based at the University of Waterloo, Ontario.[30] Using data from 2017/18, Vermeer et al. (2021) found that public health engagement in joint problem solving with schools was associated with a higher odds for better mental health, higher odds of meeting screen time guidelines, and lower odds of bullying others.[26] However, public health engagement, in any form, was not found to be associated with healthy eating, physical activity, or substance use.[26] Burnett et al. (2022) did a similar investigation using data from 2018/19 of the COMPASS study, with a focus on substance use alone. Contrary to Vermeer et al. (2021), they found that joint problem solving was associated with increased odds of alcohol and cannabis use. For other forms of engagement and types of substance use (cigarette and e-cigarette use), no association was observed. When schools were stratified by low or high overall substance use, differing findings were observed regarding the relationship between public health unit engagement and substance use. For example, joint implementation of a program to address substance use was associated with higher odds of cannabis use in low-use schools, but a lower odds of cannabis use in high-use schools. Provision of material resources or information was associated with lower cigarette use in high-use schools, but this association was absent in low-use schools. These findings by Burnett et al. (2022) indicate an inconsistent direction of association between PHU engagement and substance use in a cross-sectional analysis.

A limitation of cross-sectional studies is that temporality cannot be assessed. Thus, it is unclear whether PHU engagement was a response to an identified need in schools, or if substance use patterns were impacted by PHU engagement. To build on findings by Burnett et al. (2022), this study will use data collected longitudinally to investigate the association between PHU engagement and adolescent substance use.

3.2 Methods

3.2.1 Study Design and Study Sample

A longitudinal analysis was conducted to investigate the association between PHU engagement in school-based substance use prevention and adolescent use of alcohol, cannabis, cigarettes, e-cigarettes. Conducted over a three-year period from 2016/17 to 2018/19, this design can provide support for a temporal association between program implementation in 2016 and the pattern of substance use in subsequent years, though this is not enough evidence to infer a causal association. The data for this analysis were obtained from the COMPASS prospective cohort study. The COMPASS study involves administration of surveys to a convenience sample of Canadian grade 9-12 students, as well as staff at the secondary schools they attend.[30] Data on student socio-demographic information and health indicators were collected through a student questionnaire (Cq) while school level data were collected from administrators through the School Policies and Programs (SPP) questionnaire.[30] The Cq is a pen-and-paper survey that can be completed in a 30-40 minute sitting.[31] Parental consent is obtained through an active information-passive consent process.[32] Parents are informed of the study through various school media channels, and are determined to have given consent unless they ask that their child be excluded. The SPP is completed by a school staff member who has knowledge on the topic of school policies and practices.[30]

This analysis focused on grade 9-12 students in Ontario, Alberta and British Columbia who participated in year 5 of the COMPASS study (2016/17) and had at least one follow-up in a subsequent year. The sample consisted of 17,510 students in 68 schools. After excluding those students who were missing baseline (2016/17) exposure, covariate and outcome data, a sample of 16,575 students (95% of original sample) in 68 schools remained.

3.2.2 Main Exposure

The main exposure of interest is PHU engagement in school-based substance use prevention programs. PHU engagement in addressing substance use will be identified by two questions. The first is, *"During the past 12 months, what role did your local Public Health Unit play when working with your school on tobacco or e-cigarette use for students?"* and the second is, *"During the past 12 months, what role did your local Public Health Unit play when working with your school on alcohol and/or marijuana use for students?"* Survey respondents could select all that apply from the following: (1) No contact with local public health unit (2) provided information/resources/programs (3) solved problems jointly (4) developed/implemented program activities jointly. Schools were categorized as having PHU support if they selected any one of (2) through (4). Additionally, school administrators were asked whether or not they offered any programs that address alcohol, cannabis, cigarette or e-cigarette use, and if those programs were run by the school, the local PHU, or external organizations. Schools were categorized as having PHU support if they indicated that they do have a program addressing substance use that is run by the local PHU. Although multiple options could have been selected on the SPP survey, schools with PHU engagement were categorized during data analysis by the highest level of PHU engagement they reported. Additionally, the response options of joint problem-solving and joint development/implementation of programs were combined. Thus, levels of PHU engagement from lowest to highest were: provision of information/resources/programs, joint problem solving or program development/implementation, and PHU-led program implementation. The SPP survey is based on the Healthy School Planner tool by the Joint Consortium on School Health. The Health School Planner has been previously validated and is an evidence-based online tool to help schools build healthier school environments and policies.[33]

3.2.3 Main Outcome

The outcomes of interest are current alcohol use, alcohol binge drinking, cannabis use, cigarette use or e-cigarette use. Current use was defined as self-reported use of a given substance at least once in the past month or once per month on average. Binge drinking alcohol was defined as having five or more standard drinks on one occasion. These definitions were consistent with other studies on adolescent substance use by COMPASS researchers as well as national substance use surveillance surveys.[1,17,18,34,35] A validity study of self-reported smoking

status found that self-report is a valid measure of current smoking levels among Canadians aged 12 and older.[36]

3.2.4 Individual Level Covariates

Consistent with previous literature by COMPASS researchers, this analysis included five individual level covariates to explain a portion of the variation in adolescent substance use. These were sex, grade, race, and spending money as categorical variables, and school connectedness score as a continuous variable. Sex was identified by the question, "Are you female or male?"[17,19,37] Based on the literature, gender can influence risk factors for substance use.[16,38] Given the impact of sex on the way children and adolescents are socialized and the impact of social norms and expectations on behaviour, it may be more informative to interpret sex differences as being attributable to gender rather than biological factors.[39] Thus, the remainder of this study will treat this variable as gender. Grade was one of grade 9, 10, 11, or 12. Students reported their race as being one or more of the following: White, Black, Asian, Latinx, or Other. "Other" included those who selected "other" and those who selected multiple race categories. Spending money was included as a proxy for socioeconomic status and defined as the amount of money received in a usual week for a student to spend on themselves or to save, from allowance or paid work. Response categories were "$0", "$1 to $20", $21 to $100", "$100", and "Do not know" consistent with Burnett et al. (2022) and Williams et al. (2021).[18,29] A limitation of using spending money as a proxy for SES is potential for misclassification. Students may under- or over-report their spending money, or it may change over time, as in the case of seasonal work. Moreover, students' weekly spending may not be correlated with the SES of their family as parental attitudes on weekly allowance money may differ independently of SES. Nevertheless, it is the best proxy available for SES.

Social connectedness was quantified as a composite score based on six questions asking students about their feelings of closeness with others at school, their feelings of belongingness, happiness, fair treatment, and safety at school, as well as the importance to them of getting good grades. School connectedness was measured using a scale adapted from the National Longitudinal Study of Adolescent Health school connectedness scale, which has been found in a study of 18 different sociocultural groups to have an acceptable reliability (α = .82 to .88) and concurrent validity (r = .44 to .55).[40,41]

3.2.5 School Level Covariates

Covariates at the school level were school enrolment size, median household income, rurality, and the province in which the school was located. School enrolment size, the total number of students enrolled in 2016/17, was defined as a categorical variable whereby small, medium and large schools respectively, were those that had 1-500, 501-1000, or more than 1000 students enrolled. Median household income was the median after-tax household income of the census division in which the school was located, determined using the school postal code. Rurality was determined using forward sortation area, whereby a zero as the second character denotes an area as being rural, and a non-zero denotes an area as being urban.

3.2.6 Statistical Analysis

There were two research questions investigated:

1. Was public health engagement in 2016/17 associated with adolescent substance use over time?

2. Did different methods of public health engagement in 2016/17 have different associations with adolescent substance use over time compared to the absence of public health engagement?

For the first question, any type of PHU engagement at baseline was compared with an absence of PHU engagement as the reference category. The second question also studied PHU engagement at baseline, but with dummy variables for each different method of engagement. Three methods of engagement were identified, with no PHU engagement as a reference category: PHU provision of information/resources/programs; PHU engagement in solving problems and/or implementing programs jointly at baseline; and PHU-run programs. A longitudinal association was studied by including an interaction between baseline PHU engagement and year. An additional analysis was conducted to account for the time varying nature of the exposure variable. This analysis explored the association between no engagement at all, intermittent engagement, or consistent engagement across the three years, and substance use over time. Results are presented in Appendix B.

Observations in this dataset were nested within students, as students were followed up over time. There was also nesting of students within schools. Because of the likelihood of within student and within school similarities, a multilevel model was used to account for the hierarchical data structure. One advantage of using a multilevel model in a longitudinal analysis is that it allows for unbalanced student level data such that each student may have different numbers of repeated observations. This is useful because not all students had outcome measures for all three years. Despite some missingness, students could be retained in the sample to maintain statistical power. It was assumed in the multilevel model that missing data occurred at random (MAR). Equations for the three levels of this hierarchically nested data are shown in Appendix F. Level-1 represents repeated observations for a given student, level-2 represents student characteristics, and level-3 represents school characteristics.

The first step in running the multilevel model was to fit a model including only the variables of time and substance use, to determine whether there is a change in the outcome over time. This intercept-only model was used to calculate the 95% plausible value ranges, which indicate the range of variability between schools, for each study outcome. The intercept-only model was also used to determine the intraclass correlation coefficients (ICC), which indicate the proportion of variability in substance use explained by student and school characteristics. The second step was to fit an unadjusted model to study only the association between PHU engagement and substance use, without accounting for any student or school level covariates. The third step was to fit adjusted models that accounted for student and school level covariates. The final step was to check for cross-level interaction effects between PHU engagement and sex, as some previous COMPASS research on substance use has involved stratification of participants due to differences by sex.[18]

Finally, it is important to verify whether there is enough power to detect a statistically significant association between exposure and outcome. The limiting factor in a multilevel analysis is the highest grouping variable – in this case, the number of schools. Simulation studies have shown that, in 2-level model, a level 2 sample size of 50 or more will give unbiased estimates of standard errors of the estimated regression coefficients.[97,98] Because the COMPASS data used in this analysis are obtained from a sample of more than 50 schools, the sample size was considered sufficiently large and the analyses had sufficient statistical power. All analyses

were completed using STATA version 17.0 (StataCorp. 2021. *Stata Statistical Software: Release 17*. College Station, TX: StataCorp LLC.)

3.3 Results

3.3.1 Descriptive statistics

Tables 3.1.1 and 3.1.2 describe the individual and school level characteristics of the study sample (n=16,575) at baseline, 2016/17. 52% of the sample was female. 75% of students were in grade 9 or 10, 25% were in grade 11 or 12, and 71% identified as being White. At baseline, 25% of students reported using alcohol in the past month and 13% reported binge drinking in the past month. 9%, 6% and 9% of students reported past-month use of cannabis, cigarettes and electronic cigarettes respectively. There was an increase in substance use with advancing grade level (Figure 3.1)

The majority of sample schools (n=68) were in Ontario (84%), followed by some in Alberta (10%) and British Columbia (6%). Of the 68 schools, 85% were located in an urban area. School size fluctuated over the three years, however at baseline, 29% of schools were categorized as being small, 56% as being medium-size, and 15% as being large. Schools were in census divisions with median household income ranging from $53,127 to $87,183, and the median value across all census divisions of this study sample was $60,652 (standard deviation (SD)=8,053).

In 2016/17, 44 of 68 schools (65%) engaged with their local PHU in addressing alcohol and cannabis use. More specifically, 20 (29%) schools received information/resources/programs from their local PHU and 8 (12%) solved problems jointly with their local PHU or developed/implemented program activities jointly. PHUs had programs outside of class/curriculum to address alcohol and cannabis use in 12 (18%) and 15 (22%) of schools respectively, and 11 (16%) schools had both alcohol and cannabis programs. Similarly, 44 of 68 (65%) schools had their local PHUs engaged in addressing tobacco and e-cigarette use. 21 (31%) schools received information/resources/programs from their local PHU and 6 (9%) schools solved problems or developed/implemented program activities jointly with their local PHU. PHUs had programs outside of class/curriculum to address tobacco and e-cigarette use in 15 (22%) and 10 (15%) schools respectively, and 8 (12%) had both tobacco and e-cigarette programs. Students exposed to PHU engagement in 2016/17 had a slightly lower prevalence of

alcohol, cannabis and e-cigarette use at baseline compared to students who were not exposed to PHU engagement (Table 3.1.3 and 3.1.4). Schools with any type of PHU engagement were similar to schools with no PHU engagement in 2016/17 (Appendix D). Notably however, though the difference was not statistically significant, a higher proportion of schools with PHU engagement were in an urban area and were large in enrolment size as compared to schools without PHU engagement. If this difference is real, the lack of statistical significance may be due to a relatively small sample size in at least one category of school size or rurality.

Table 3.1.1. Demographic characteristics of cohort with complete data at baseline (n=16,575).

Variable	n	%
Sex		
Female	8,613	52.0
Male	7,962	48.0
Grade		
9	6,430	38.8
10	6,031	36.4
11	3,849	23.2
12	265	1.6
Race		
White	11,823	71.3
Black	550	3.3
Asian	1,234	7.4
Latinx	405	2.4
Other	2,563	15.5
Spending money		
Zero	3,183	19.2
$1-$20	5,185	31.3
$21-$100	3,954	23.9
$100+	2,064	12.5
Don’t know	2,189	13.2
Binge drinking		
No	14,436	87.1
Yes	2,139	12.9
Alcohol use		
No	12,449	75.1
Yes	4,126	24.9
Cannabis use		
No	15,046	90.8
Yes	1,529	9.2
Cigarette use		
No	15,603	94.1
Yes	972	5.9
E-cigarette use		
No	15,048	90.8
Yes	1,527	9.2

Table 3.1.2. Characteristics of schools at baseline (n=68).

Variable	n	**%**
Enrolment size		
Small	20	29.4
Medium	38	55.9
Large	10	14.7
Missing		
Rurality		
Urban	58	85.3
Rural	10	14.7
Province		
Ontario	57	83.8
Alberta	7	10.3
British Columbia	4	5.9
Area level median income		
Mean, SD	64,399	8,355.71
Median	60,243	

Table 3.1.3. Baseline characteristics of students exposed to public health unit engagement (PHE) in addressing alcohol/cannabis use compared to students unexposed to PHE in 2016/17 (n=16,575)

	Exposure to baseline PHE		**No exposure to baseline PHE**		**Chi Square / T-test**		
Variable	**n**	**%**	**n**	**%**	**df**	**test statistic**	**p-value**
Sex							
Female	5,942	52.29	2,671	51.26	1	1.52	0.22
Male	5,422	47.71	2,540	48.74			
Grade							
9	4,527	39.84	1,903	36.52	3	36.02	<0.001
10	4,002	35.22	2,029	38.94			
11	2,627	23.12	1,222	23.45			
12	208	1.83	57	1.09			
Race							
White	7,975	70.18	3,848	73.84	4	58.50	<0.001
Black	426	3.75	124	2.38			
Asian	807	7.10	427	8.19			
Latinx	308	2.71	97	1.86			
Other	1,848	16.26	715	13.72			
Weekly Spending Money	2,217	19.51	966	18.54	4	13.26	0.01
Zero	3,621	31.86	1,564	30.01			
$1-$20	2,680	23.58	1,274	24.45			
$21-$100	1,365	12.01	699	13.41			
$100+	1,481	13.03	708	13.59			
Don’t know							
Binge drinking							
No	9,933	87.41	4,503	86.41	1	3.14	0.08
Yes	1,431	12.59	708	13.59			
Alcohol use							
No	8,625	75.90	3,824	73.38	1	12.08	0.001
Yes	2,739	24.10	1,387	26.62			
Cannabis use							
No	10,351	91.09	4,695	90.10	1	4.16	0.04
Yes	1,013	8.91	516	9.90			

	Mean	SD	Mean	SD			
School connectedness							
Mean, SD	18.45	3.09	18.58	3.03	16573	2.47	0.01

Table 3.1.4. Baseline characteristics of students exposed to public health unit (PHU) engagement in addressing tobacco/e-cigarette use compared to students unexposed to PHU engagement in 2016/17 (n=16,575).

	Exposure to engagement		No exposure to engagement		Chi Square / T-test		
Variable	**n**	**%**	**n**	**%**	**df**	**test statistic**	**p-value**
Sex							
Female	6,008	52.44	2,605	50.89	1	3.43	0.06
Male	5,448	47.56	2,514	49.11			
Grade							
9	4,534	39.58	1,896	37.04	3	25.25	<0.001
10	4,073	35.55	1,958	38.25			
11	2,640	23.04	1,209	23.62			
12	209	1.82	56	1.09			
Race							
White	8,179	71.39	3,644	71.19	4	94.50	<0.001
Black	438	3.82	112	2.19			
Asian	742	6.48	492	9.61			
Latinx	315	2.75	90	1.76			
Other	1,782	15.55	781	15.25			
Weekly Spending Money							
Zero	2,247	19.61	936	18.28	4	20.48	<0.001
$1-$20	3,652	31.88	1,533	29.95			
$21-$100	2,683	23.42	1,271	24.83			
$100+	1,360	11.87	704	13.75			
Don’t know	1,514	13.22	675	13.19			
Cigarette use							
No	10,809	94.35	4,794	93.65	1	3.15	0.08
Yes	647	5.65	325	6.35			
E-cigarette use							
No	10,473	91.42	4,575	89.37	1	17.72	<0.001
Yes	983	8.58	544	10.63			

	Mean	SD	Mean	SD			
School Connectedness Mean, SD	18.45	3.08	18.58	3.07	16573	2.48	0.01

Missingness of information at baseline was associated with gender, race, and school connectedness (Appendix E). Males, those self-identifying as Black or Other, and those with low school connectedness were more likely to have been excluded due to missing data at baseline. Those excluded were also more likely to attend a school in an area belonging to the highest quartile of median after-tax household income. Additionally, there was significant attrition. There were 4,114 grade 11 and 12 students at baseline, 25% of the total sample. As these students graduated, it was expected that the sample would be reduced to 75% of the original size, approximately 12,431 students, by 2018/19. However, the actual remaining sample was 8,422 students, only 51% of the baseline sample, indicating significant loss to follow up for reasons other than graduation. Those who remained in the study until 2018/19 were more likely to be in grade 9 at baseline, have little to no weekly spending money, and experience higher school connectedness. (Appendix C).

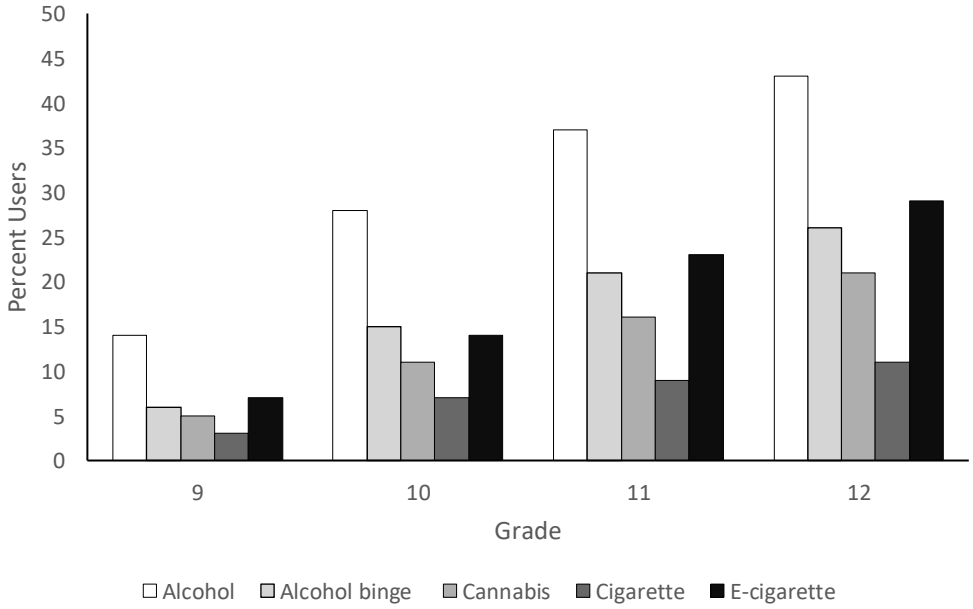

Figure 3.1. Proportion of grade 9-12 secondary students in COMPASS year 2016/17 who used alcohol (any use or binge drinking), cannabis, cigarettes, or e-cigarettes in the past month or at least monthly.

3.3.2 Research Question 1: Is public health engagement in 2016/17 associated with adolescent substance use over time?

For all outcomes, adjusted odds ratio estimates were conditional on the random effect and controlled for individual and school level covariates. There was no evidence of an interaction between PHU engagement and students' sex. Overall, there was no association between PHU engagement and substance use over time (Figure 3.2). Although the unadjusted models indicated an increase in substance use over time, there was no association between time and substance use once grade was adjusted for (Figure 3.2). Those in grades 10, 11 and 12 each had larger odds of using any substance compared to those in grade 9, with a larger effect size for those in higher grades.

Alcohol use

Based on the intercept-only model for past-month alcohol use, 6% of the variation in alcohol use is attributable to between-school differences (ICC: 0.06; 95% CI: 0.04, 0.08) and 64% of the variation is attributable to between-student differences (ICC: 0.64; 95% CI: 0.62, 0.66). The prevalence of past-month alcohol use across schools ranged from 5.8% to 53.3% (see Appendix G for formula used to calculate plausible range). Boys had a higher odds of alcohol use compared to girls (adjusted odds ratio (AOR): 1.24; 95% CI: 1.12, 1.38). No statistically significant association between baseline PHU engagement in addressing alcohol/cannabis use and past month alcohol use was observed (AOR: 1.01, 95% CI: 0.69, 1.47) (Table 3.2.1). Similarly, there was no significant interaction between PHU engagement and year. There was no difference in alcohol use two years later between those exposed to PHU engagement in 2016/17 compared to those who were not exposed (AOR: 1:08, 95% CI: 0.73, 1.60).

Alcohol binge drinking

Based on the intercept-only model for past-month binge drinking, 7% of the variation in binge drinking is attributable to between-school differences (ICC: 0.07; 95% CI: 0.05, 0.09) and 65% of the variation in alcohol use is attributable to between-student differences (ICC: 0.65; 95% CI: 0.63, 0.67). The prevalence of past-month binge drinking across schools ranged from 1.6% to 26.0%. Boys had a higher odds of binge drinking compared to girls (AOR: 1.39; 95% CI: 1.23, 1.56). Similar to overall alcohol use, no statistically significant association was

observed between PHU engagement in addressing alcohol/cannabis use and past-month binge drinking (AOR: 1.11, 95% CI: 0.75, 1.69) (Table 3.2.2). Likewise, there was no significant interaction between PHU engagement and year. There was no difference in binge drinking two years later between those exposed to PHU engagement in 2016/17 compared to those who were not exposed (AOR: 1.17, 95% CI: 0.77, 1.79).

Cannabis use

Based on the intercept-only model for past-month cannabis use, 2% of the variation in cannabis use is attributable to between-school differences (ICC: 0.02; 95% CI: 0.02, 0.03) and 73% of the variation is attributable to between-student differences (ICC: 0.73; 95% CI: 0.71, 0.75). The prevalence of past-month cannabis use across schools ranged from 1.1% to 7.8%. Compared to alcohol use, past-month cannabis use appears to be much less influenced by school level factors than student level factors. Boys had a higher odds of cannabis use compared to girls (AOR: 2.08; 95% CI: 1.79, 2.41). Although there was no statistically significant association between baseline PHU engagement in addressing alcohol/cannabis use and past-month cannabis use, the adjusted odds ratio observed was moderately protective (AOR: 0.73, 95% CI: 0.51, 1.03) (Table 3.2.3). Similarly, there was no significant interaction between PHU engagement and year. There was no difference in cannabis use by 2018/19 between those exposed to PHU engagement in 2016/17 compared to those who were not exposed (AOR: 0.93, 95% CI: 0.66, 1.31).

Cigarette use

Based on the intercept-only model for past-month cigarette use, 10% of the variation in cigarette use is attributable to between-school differences (ICC: 0.10; 95% CI: 0.07, 0.14) and 76% of the variation is attributable to between-student differences (ICC: 0.76; 95% CI: 0.73, 0.79). The prevalence of past-month cigarette use across schools ranged from 0.1% to 8.9%. School level factors appear to have a greater influence on past-month cigarette use as compared to alcohol or cannabis use. Boys had a higher odds of cigarette use compared to girls (AOR: 2.03; 95% CI: 1.73, 2.41). As with alcohol or cannabis use, there was no association between PHU engagement in addressing cigarette/e-cigarette use and past month cigarette use (AOR: 0.98, 95% CI: 0.58, 1.63) and no significant interaction with year (Table 3.2.4). There was no

difference in cigarette use by 2018/19 between those exposed to PHU engagement in 2016/17 compared to those who were not exposed (AOR: 0.78, 95% CI: 0.46, 1.34).

E-cigarette use

Based on the intercept-only model for past-month e-cigarette use, 5% of the variation in e-cigarette use is attributable to between-school differences (ICC: 0.05; 95% CI: 0.03, 0.07) and 49% of the variation is attributable to between-student differences (ICC: 0.49; 95% CI: 0.47, 0.51). The prevalence of past-month e-cigarette use across schools ranged from 3.9% to 25.6%. Boys had a higher odds of e-cigarette use compared to girls (AOR: 2.67; 95% CI: 2.38, 2.99). Similar to cannabis use, although there was no statistically significant association between PHU engagement in addressing cigarette/e-cigarette use and past month e-cigarette use, the association observed was moderately protective (AOR: 0.83, 95% CI: 0.59, 1.17) (Table 3.2.5). There was no significant interaction between PHU engagement and year. There was no difference in e-cigarette use by 2018/19 between those exposed to PHU engagement in 2016/17 compared to those who were not exposed (AOR: 0.88, 95% CI: 0.62, 1.23).

Table 3.2.1. Association between public health engagement[1] in 2016/17 and adolescent monthly alcohol use over a three-year period from 2016/17 to 2018/19.

	Past-month alcohol use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.11 (0.08, 0.16)**	**0.09 (0.06, 0.13)**	**0.14 (0.08, 0.24)**
Engagement (ref: None)			
Any	0.82 (0.54, 1.24)	0.85 (0.59, 1.23)	1.01 (0.69, 1.47)
Time (ref: 2016)			
2017	**2.86 (2.52, 3.25)**	1.07 (0.93, 1.24)	1.07 (0.93, 1.24)
2018	**5.04 (4.31, 5.89)**	0.96 (0.79, 1.16)	0.96 (0.79, 1.16)
Engagement x Time			
Engaged 2017	1.03 (0.88, 1.20)	0.98 (0.84, 1.14)	0.98 (0.84, 1.14)
Engaged 2018	1.09 (0.90, 1.31)	1.08 (0.89, 1.30)	1.08 (0.89, 1.30)
Grade (ref: 9)			
10		**3.89 (3.38, 4.47)**	**3.89 (3.39, 4.47)**
11		**7.51 (6.33, 8.92)**	**7.53 (6.34, 8.94)**
12		**12.05 (9.66, 15.03)**	**12.07 (9.68, 15.06)**
Sex (ref: Female)			
Male		**1.24 (1.12, 1.38)**	**1.24 (1.12, 1.38)**
Race (ref: White)			
Black		**0.38 (0.27, 0.52)**	**0.38 (0.28, 0.53)**
Asian		**0.18 (0.14, 0.23)**	**0.19 (0.15, 0.24)**
Latinx		0.87 (0.62, 1.22)	0.88 (0.62, 1.23)
Other		**0.71 (0.61, 0.82)**	**0.71 (0.61, 0.82)**

Table 3.2.1. Continued.

Variable	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)
Spending Money (ref: $0)			
$1-$20		**1.72 (1.50, 1.97)**	**1.72 (1.50, 1.97)**
$21-$100		**3.35 (2.93, 3.84)**	**3.35 (2.92, 3.83)**
$100+		**4.59 (3.98, 5.28)**	**4.58 (3.97, 5.27)**
Do not know		**1.78 (1.53, 2.09)**	**1.78 (1.52, 2.09)**
Connectedness		**0.93 (0.92, 0.94)**	**0.93 (0.92, 0.94)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.89 (0.56, 1.43)
3rd quartile			1.08 (0.68, 1.72)
4th quartile			**0.56 (0.32, 1.00)**
Rural (ref: urban)			
Rural			0.80 (0.48, 1.31)
School Size (ref: Small)			
Medium			**0.55 (0.37, 0.83)**
Large			**0.47 (0.27, 0.80)**
Province (ref: Ontario)			
Alberta			1.91 (0.95, 3.83)
British Columbia			0.68 (0.31, 1.49)

[1] Public health engagement is defined as any form of engagement by the local public health unit, including providing resources, solving problems jointly, or running programs to address alcohol and cannabis use.
Bold indicates statistical significance at $p \leq 0.05$

Table 3.2.2. Association between public health engagement[1] in 2016/17 and adolescent monthly alcohol binge drinking over a three-year period from 2016/17 to 2018/19.

	Past-month binge drinking		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.02 (0.02, 0.03)**	**0.02 (0.01, 0.03)**	**0.02 (0.01, 0.05)**
Engagement (ref: None)			
Any	0.93 (0.61, 1.43)	0.92 (0.61, 1.38)	1.11 (0.73, 1.69)
Time (ref: 2016)			
2017	**3.12 (2.68, 3.64)**	1.16 (0.98, 1.37)	1.16 (0.98, 1.37)
2018	**5.35 (4.44, 6.45)**	1.04 (0.83, 1.30)	1.04 (0.83, 1.30)
Engagement x Time			
Engaged 2017	0.92 (0.77, 1.10)	0.90 (0.75, 1.08)	0.90 (0.75, 1.08)
Engaged 2018	1.07 (0.86, 1.33)	1.05 (0.84, 1.32)	1.05 (0.84, 1.31)
Grade (ref: 9)			
10		**4.40 (3.67, 5.28)**	**4.40 (3.67, 5.28)**
11		**8.52 (6.87, 10.57)**	**8.52 (6.87, 10.57)**
12		**13.58 (10.43, 17.68)**	**13.56 (10.42, 17.66)**
Sex (ref: Female)			
Male		**1.39 (1.24, 1.56)**	**1.39 (1.23, 1.56)**
Race (ref: White)			
Black		**0.66 (0.45, 0.95)**	**0.67 (0.47, 0.97)**
Asian		**0.27 (0.20, 0.37)**	**0.28 (0.21, 0.38)**
Latinx		1.15 (0.78, 1.68)	1.15 (0.79, 1.69)
Other		**0.82 (0.69, 0.97)**	**0.82 (0.70, 0.97)**

Table 3.2.2. Continued

Variable	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)
Spending Money (ref: $0)			
$1-$20		**1.65 (1.39, 1.96)**	**1.65 (1.39, 1.97)**
$21-$100		**3.49 (2.95, 4.12)**	**3.48 (2.95, 4.11)**
$100+		**4.94 (4.17, 5.86)**	**4.93 (4.16, 5.84)**
Do not know		**1.79 (1.48, 2.18)**	**1.79 (1.47, 2.18)**
Connectedness		**0.92 (0.90, 0.93)**	**0.92 (0.90, 0.93)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.91 (0.54, 1.52)
3rd quartile			0.93 (0.57, 1.54)
4th quartile			**0.44 (0.23, 0.82)**
Rural (ref: urban)			
Rural			0.96 (0.56, 1.65)
School Size (ref: Small)			
Medium			**0.62 (0.40, 0.97)**
Large			**0.53 (0.29, 0.95)**
Province (ref: Ontario)			
Alberta			**3.18 (1.48, 6.81)**
British Columbia			0.67 (0.28, 1.58)

[1] Public health engagement is defined as any form of engagement by the local public health unit, including providing resources, solving problems jointly, or running programs to address alcohol and cannabis use.
Bold indicates statistical significance at $p \leq 0.05$

Table 3.2.3. Association between public health engagement[1] in 2016/17 and adolescent monthly cannabis use over a three-year period from 2016/17 to 2018/19.

	Past-month cannabis use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.002 (0.001, 0.003)**	**0.03 (0.01, 0.05)**	**0.03 (0.02, 0.06)**
Engagement (ref: None)			
Any	0.80 (0.56, 1.15)	0.81 (0.57, 1.13)	0.73 (0.51, 1.03)
Time (ref: 2016)			
2017	**4.92 (4.00, 6.06)**	**1.54 (1.24, 1.91)**	**1.54 (1.24, 1.91)**
2018	**11.48 (8.95, 14.74)**	**1.83 (1.38, 2.42)**	**1.83 (1.38, 2.42)**
Engagement x Time			
Engaged 2017	1.02 (0.80, 1.31)	0.96 (0.76, 1.21)	0.96 (0.76, 1.21)
Engaged 2018	**1.38 (1.03, 1.83)**	1.28 (0.97, 1.69)	1.28 (0.97, 1.69)
Grade (ref: 9)			
10		**5.18 (4.03, 6.66)**	**5.19 (4.04, 6.68)**
11		**9.67 (7.15, 13.07)**	**9.71 (7.18, 13.13)**
12		**15.88 (11.06, 22.79)**	**15.95 (11.11, 22.90)**
Sex (ref: Female)			
Male		**2.08 (1.79, 2.41)**	**2.08 (1.79, 2.41)**
Race (ref: White)			
Black		1.33 (0.87, 2.02)	1.37 (0.90, 2.09)
Asian		**0.22 (0.15, 0.33)**	**0.23 (0.15, 0.34)**
Latinx		1.31 (0.81, 2.12)	1.30 (0.80, 2.10)
Other		**1.61 (1.31, 1.97)**	**1.62 (1.32, 1.99)**

Table 3.2.3. Continued

Variable	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)
Spending Money (ref: $0)			
$1-$20		**1.81 (1.46, 2.23)**	**1.81 (1.46, 2.24)**
$21-$100		**3.21 (2.62, 3.95)**	**3.21 (2.61, 3.95)**
$100+		**4.50 (3.66, 5.54)**	**4.49 (3.64, 5.52)**
Do not know		**1.68 (1.31, 2.15)**	**1.68 (1.31, 2.15)**
Connectedness		**0.80 (0.78, 0.81)**	**0.80 (0.78, 0.81)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			1.38 (0.93, 2.04)
3rd quartile			0.94 (0.64, 1.38)
4th quartile			0.67 (0.41, 1.09)
Rural (ref: urban)			
Rural			**0.51 (0.33, 0.78)**
School Size (ref: Small)			
Medium			0.92 (0.65, 1.31)
Large			0.91 (0.58, 1.42)
Province (ref: Ontario)			
Alberta			1.49 (0.82, 2.73)
British Columbia			0.84 (0.44, 1.60)

[1] Public health engagement is defined as any form of engagement by the local public health unit, including providing resources, solving problems jointly, or running programs to address alcohol and cannabis use.
Bold indicates statistical significance at $p \leq 0.05$

Table 3.2.4. Association between public health engagement[1] in 2016/17 and adolescent monthly cigarette use over a three-year period from 2016/17 to 2018/19.

Variable	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)
Constant	**0.004 (0.002, 0.006)**	**0.07 (0.03, 0.14)**	**0.09 (0.04, 0.23)**
Engagement (ref: None)			
Any	0.90 (0.47, 1.72)	0.84 (0.47, 1.52)	0.98 (0.58, 1.63)
Time (ref: 2016)			
2017	**3.60 (2.92, 4.48)**	**2.18 (1.72, 2.75)**	**2.16 (1.72, 2.75)**
2018	**3.63 (2.80, 4.71)**	**1.72 (1.25, 2.36)**	**1.72(1.25, 2.36)**
Engagement x Time			
Engaged 2017	**0.79 (0.61, 1.02)**	0.79 (0.62, 1.02)	0.79 (0.62, 1.02)
Engaged 2018	**0.79 (0.58, 1.07)**	0.80 (0.59, 1.11)	0.80 (0.59, 1.09)
Grade (ref: 9)			
10		**2.51 (1.97, 3.19)**	**2.51 (1.97, 3.19)**
11		**4.01 (3.00, 5.37)**	**4.01 (3.00, 5.37)**
12		**4.71 (3.29, 6.75)**	**4.71 (3.29, 6.75)**
Sex (ref: Female)			
Male		**2.05 (1.73, 2.41)**	**2.03 (1.73, 2.41)**
Race (ref: White)			
Black		0.81 (0.48, 1.38)	0.85 (0.50, 1.45)
Asian		**0.32 (0.21, 0.50)**	**0.33 (0.21, 0.52)**
Latinx		0.68 (0.36, 1.30)	0.69 (0.36, 1.31)
Other		**1.60 (1.28, 1.99)**	**1.62 (1.28, 2.01)**

Table 3.2.4. Continued

Variable	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)
Spending Money (ref: $0)			
$1-$20			**2.18 (1.68, 2.86)**
$21-$100			**4.44 (3.35, 5.81)**
$100+			**5.21 (3.82, 7.10)**
Do not know			**1.77 (1.28, 2.46)**
Connectedness			**0.77 (0.75, 0.79)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			1.52 (0.79, 2.92)
3rd quartile			1.31 (0.66, 2.56)
4th quartile			**0.40 (0.17, 0.93)**
Rural (ref: urban)			
Rural			1.16 (0.57, 2.34)
School Size (ref: Small)			
Medium			**0.52 (0.29, 0.93)**
Large			**0.30 (0.13, 0.66)**
Province (ref: Ontario)			
Alberta			**3.97 (1.43, 11.13)**
British Columbia			0.73 (0.22, 2.34)

[1] Public health engagement is defined as any form of engagement by the local public health unit, including providing resources, solving problems jointly, or running programs to address alcohol and cannabis use.
Bold indicates statistical significance at $p \leq 0.05$

Table 3.2.5. Association between public health engagement[1] in 2016/17 and adolescent monthly e-cigarette use over a three-year period from 2016/17 to 2018/19.

	Past-month e-cigarette use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.01 (0.01, 0.02**	**0.01 (0.01, 0.02)**	**0.02 (0.01, 0.03)**
Engagement (ref: None)			
Any	0.74 (0.50, 1.08)	0.74 (0.51, 1.07)	0.83 (0.59, 1.17)
Time (ref: 2016)			
2017	**6.65 (5.63, 7.84)**	**4.14 (3.47, 4.95)**	**4.15 (3.47, 4.95)**
2018	**22.07 (18.03, 27.00)**	**10.40 (8.26, 13.08)**	**10.40 (8.27, 13.09)**
Engagement x Time			
Engaged 2017	1.01 (0.83, 1.23)	0.96 (0.79, 1.16)	0.96 (0.79, 1.16)
Engaged 2018	1.14 (0.91, 1.42)	1.06 (0.85, 1.32)	1.06 (0.85, 1.32)
Grade (ref: 9)			
10		**1.52 (1.28, 1.81)**	**1.52 (1.28, 1.81)**
11		**1.87 (1.52, 2.29)**	**1.87 (1.52, 2.29)**
12		**2.08 (1.63, 2.66)**	**2.08 (1.63, 2.67)**
Sex (ref: Female)			
Male		**2.67 (2.38, 2.99)**	**2.67 (2.38, 2.99)**
Race (ref: White)			
Black		0.72 (0.51, 1.01)	0.73 (0.52, 1.03)
Asian		**0.28 (0.21, 0.36)**	**0.28 (0.21, 0.36)**
Latinx		1.09 (0.75, 1.57)	1.08 (0.75, 1.56)
Other		1.03 (0.88, 1.20)	1.03 (0.88, 1.20)

Table 3.2.5. Continued**.**

Variable	Model 1 (95% CI)	Model 2 (95% CI)	Model 3 (95% CI)
Spending Money (ref: $0)			
$1-$20		**2.13 (1.80, 2.53)**	**2.14 (1.80, 2.53)**
$21-$100		**3.82 (3.25, 4.50)**	**3.82 (3.24, 4.50)**
$100+		**5.79 (4.90, 6.85)**	**5.78 (4.89, 6.83)**
Do not know		**1.87 (1.54, 2.27)**	**1.87 (1.54, 2.26)**
Connectedness		**0.92 (0.91, 0.94)**	**0.93 (0.91, 0.94)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.79 (0.52, 1.21)
3rd quartile			0.85 (0.55, 1.31)
4th quartile			**0.45 (0.27, 0.76)**
Rural (ref: urban)			
Rural			0.77 (0.49, 1.23)
School Size (ref: Small)			
Medium			1.00 (0.68, 1.46)
Large			0.82 (0.49, 1.36)
Province (ref: Ontario)			
Alberta			**2.88 (1.49, 5.56)**
British Columbia			1.95 (0.93, 4.09)

[1] Public health engagement is defined as any form of engagement by the local public health unit, including providing resources, solving problems jointly, or running programs to address alcohol and cannabis use.
Bold indicates statistical significance at $p \leq 0.05$

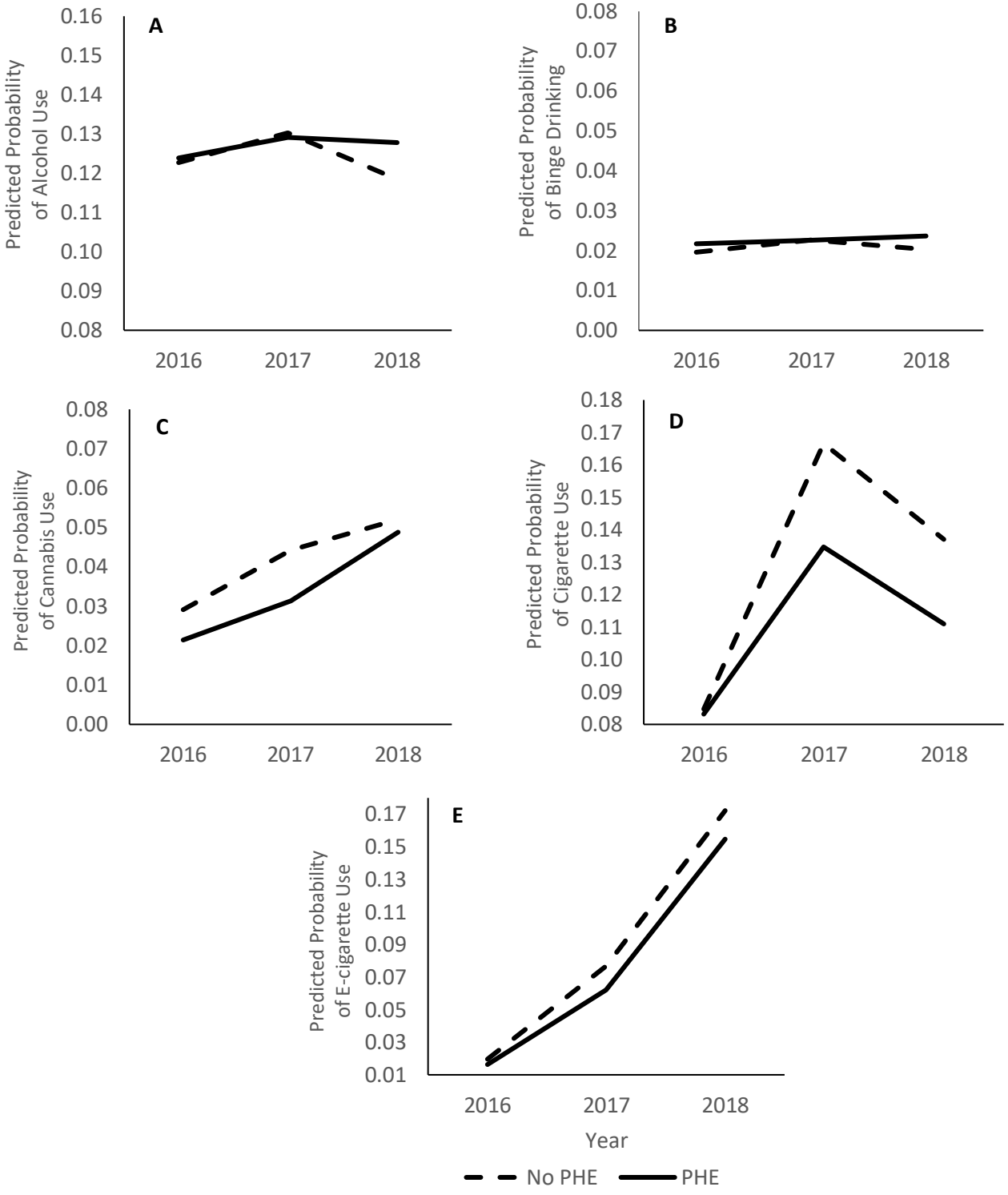

Figure 3.2. Predicted Probability of adolescent alcohol use, binge drinking, cannabis use, cigarette use, and e-cigarette use (A-E respectively) by public health unit engagement in COMPASS secondary schools from 2016/17 to 2018/2019.

3.3.3 Research Question 2: Do different methods of public health engagement in 2016/17 have different associations with adolescent substance use over time compared to the absence of public health engagement?

For all outcomes, adjusted odds ratio estimates were conditional on the random effect and controlled for individual and school level covariates.

Alcohol use

Both time, in reference to baseline, and higher grades compared to grade 9, were associated with increased odds of alcohol use. Boys had a higher odds of alcohol use compared to girls (AOR: 1.24; 95% CI: 1.12, 1.38). While there was a non-significant association between overall PHU engagement and alcohol use, the association varied by method of engagement. Though non-significant, the unadjusted odds of alcohol use at baseline for those exposed to PHU-run programs in 2016/17 compared to those with no PHU engagement was 0.62 (95% CI: 0.37, 1.03) (Table 3.3.1 and Figure 3.3). After adjusting for student and school covariates, this association remained moderately protective but statistically non-significant (AOR: 0.80; 95% CI: 0.51, 1.26). PHU provision of information/resources/programs, and PHU engagement in solving problems and/or implementing programs jointly, were both associated with higher odds of adolescent alcohol use at baseline, after controlling for other factors, but estimates were not statistically significant (AOR 1.06; CI: 0.67, 1.66 and AOR 1.23; CI: 0.69, 2.20 respectively). There was no significant longitudinal association between any method of baseline PHU engagement and alcohol use.

Alcohol binge drinking

Increases in both time and grade were associated with increased odds of alcohol binge drinking. Boys had a higher odds of alcohol binge drinking compared to girls (AOR: 1.39; 95% CI: 1.24, 1.56). In the unadjusted model, there was a lower, non-significant odds of binge drinking at baseline for those exposed to PHU-run programs compared to those not exposed to PHU-run programs (OR: 0.84; 95% CI: 0.49, 1.42). However, this non-significant effect was absent after controlling for other covariates (AOR: 0.99; 95% CI: 0.60, 1.64) (Table 3.3.2 and Figure 3.3). Joint program implementation/problem solving was not associated with binge drinking at baseline (AOR: 0.94; 95% CI: 0.49, 1.78). For PHU provision of

information/resources/ programs, an odds ratio of 1.30 suggested moderately increased binge drinking at baseline for those with this exposure compared to those without, though this was not statistically significant (AOR: 1.30, 95% CI: 0.78, 2.15). Interestingly, there was a significant, protective interaction between PHU provision of information/resources/programs and year in 2017/18 (AOR: 0.77; 95% CI: 0.62, 0.96). As a result, despite the effect size of 1.30 at baseline, by 2017/18, there was no significant difference in the odds of binge drinking when comparing those exposed to PHU provision of information/resources/programs at baseline with those unexposed (AOR: 1.00, 95% CI: 0.61, 1.64). This suggests that PHU provision of information/resources/programs may have a protective effect over time on past-month binge drinking. On the other hand, exposure to joint problem solving or program implementation at baseline was significantly associated with an excess rise in binge drinking by 2018/19 (AOR: 1.45; 95% CI: 1.02, 2.05). Though non-significant, the adjusted odds of binge drinking for those with this exposure increased from 0.94 (95% CI: 0.49, 1.78) in 2016/17 to 1.35 (95% CI: 0.71, 2.59) in 2018/19. These results suggest that, while overall PHU engagement may have a non-significant association with binge drinking, different methods of engagement may have different and even opposing longitudinal associations with binge drinking.

Cannabis use

As with alcohol use, increases in both time and grade were associated with increased odds of cannabis use. Boys had a higher odds of cannabis use compared to girls (AOR: 2.11; 95% CI: 1.82, 2.46). PHU engagement may be protective against cannabis use at baseline, whether engagement is studied overall (AOR: 0.73; CI: 0.51, 1.03), or by method of engagement as described below (Table 3.3.3 and Figure 3.3). Students exposed to PHU engagement in the form of solving problems and/or implementing programs jointly, compared to students not exposed to PHU engagement, have a 57% reduction in the odds of baseline cannabis use (95% CI: 0.25, 0.76) after adjusting for other individual and school level factors. Though statistically non-significant, the odds of cannabis use for those exposed to PHU provision of information/resources/programs or those exposed to PHU-run programs, was 0.72 (95% CI: 0.47, 1.10) and 0.84 (95% CI: 0.55, 1.27) respectively, compared to no baseline engagement and after controlling for other factors. There was a significant interaction between PHU engagement and year, whereby those who experienced PHU joint problem solving and/or program

implementation or PHU provision of information/resources/programs, had a significantly larger increase in cannabis use by 2018/19 than those with no baseline exposure to PHU engagement. For each of these exposures, the adjusted odds of past-month cannabis use in 2018/19 were 0.78 (95% CI: 0.46, 1.31) and 1.09 (95% CI: 0.73, 1.63) times the odds for those exposed to no engagement – effect sizes that are larger in 2018/19 than at baseline. The significant interactions with year suggests that these two methods of PHU engagement may be associated with lower odds of cannabis use at baseline but with higher odds of cannabis use over time.

Cigarette use

Increases in both time and grade were associated with increased odds of cigarette use. Boys had a higher odds of cigarette use compared to girls (AOR: 2.05; 95% CI: 1.73, 2.41). There was no statistically significant association between overall PHU engagement in addressing cigarette/e-cigarette use and past-month cigarette use. Similarly, after controlling for other covariates, there was no association between PHU provision of information/resources/programs, or PHU-run programs, and baseline cigarette use (AOR: 1.02; 95% CI: 0.54, 1.92 and AOR: 0.65; 95% CI: 0.26, 1.65 respectively) (Table 3.3.4 and Figure 3.3). Though statistically non-significant, the association appears to be moderately protective when comparing PHU engagement in solving problems and/or implementing programs jointly to no PHU engagement at all, whereby the odds of baseline cigarette use for those with PHU engagement is 0.65 (95% CI: 0.26, 1.65) times the odds for those without PHU engagement, after controlling for other covariates. There was a significant interaction between PHU engagement and time, in the case of exposure to PHU-run programs. Those who were exposed to PHU-run programs at baseline had a smaller increase in their odds of cigarette use over time than those who were not exposed to PHU-run programs. After adjusting for other factors, the odds of past-month cigarette use in 2017/18 and 2018/19 for those exposed to PHU-run programs were 0.60 (95% CI: 0.32, 1.14) and 0.68 (95% CI: 0.35, 1.32) compared to those who were unexposed. The significant interaction suggests that PHU-run programs may be protective against cigarette use over time.

E-cigarette use

As with cigarette use, increases in both time and grade were associated with increased odds of e-cigarette use. Boys had a higher odds of e-cigarette use compared to girls (AOR: 2.77;

95% CI: 2.46, 3.11). There was no statistically significant association between overall PHU engagement in addressing cigarette/e-cigarette use at baseline and adolescent e-cigarette use, however, the association did vary by method of engagement. PHU provision of information/resources/programs was moderately protective against baseline e-cigarette use (AOR: 0.81, 95% CI: 0.53, 1.24), but this association was statistically non-significant (Table 3.3.5 and Figure 3.3). PHU engagement in solving problems and/or implementing programs jointly, compared to no PHU engagement, was significantly protective against baseline e-cigarette use with an AOR of 0.38 (95% CI: 0.20, 0.72), after controlling for other covariates. There was no association between exposure to PHU-led programs and e-cigarette use. Significant interactions were found between two methods of PHU engagement and year. Those exposed to PHU provision of information/resources/programs at baseline had 0.60 (95% CI: 0.40, 0.90) times the odds of e-cigarette use by 2017/18 as compared to those exposed to no PHU engagement at baseline. Conversely, PHU-school joint problem solving or program implementation at baseline, compared to no PHU engagement, was associated with a larger increase in the odds of e-cigarette use in subsequent years. For those with this exposure compared to those without, the adjusted odds of e-cigarette use in 2017/18 and 2018/19 respectively were 0.97 (95% CI: 0.55, 1.72) and 0.99 (95% CI: 0.55, 1.79), after controlling for other covariates. Similar to the case of cannabis use, the significant interactions with year suggest that PHU engagement in joint problem solving or program implementation may be associated with lower odds of e-cigarette use at baseline, but a larger increase in the odds of e-cigarette use in subsequent years.

Table 3.3.1. Association between public health engagement[1] in 2016/17, by method of engagement, and adolescent monthly alcohol use, over a three-year period from 2016/17 to 2018/19.

	Past-month alcohol use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.11 (0.08, 0.16)**	**0.08 (0.05, 0.12)**	**0.11 (0.06, 0.21)**
Engagement (ref: None)			
Method 1	0.84 (0.51, 1.37)	0.88 (0.57, 1.37)	1.06 (0.67, 1.66)
Method 2	1.37 (0.70, 2.68)	1.23 (0.69, 2.20)	1.23 (0.69, 2.20)
Method 3	0.62 (0.37, 1.03)	0.67 (0.43, 1.06)	0.80 (0.51, 1.26)
Time (ref: 2016)			
2017	**2.86 (2.52, 3.25)**	**1.38 (1.20, 1.59)**	**1.38 (1.20, 1.59)**
2018	**5.04 (4.31, 5.89)**	**1.63 (1.34, 1.98)**	**1.63 (1.34, 1.98)**
Engagement*year			
Method 1*17	0.95 (0.79, 1.14)	0.94 (0.78, 1.13)	0.94 (0.78, 1.13)
Method 1*18	0.97 (0.78, 1.22)	0.97 (0.78, 1.22)	0.97 (0.77, 1.22)
Method 2*17	1.07 (0.84, 1.37)	1.04 (0.81, 1.33)	1.04 (0.81, 1.33)
Method 2*18	1.32 (0.99, 1.78)	1.27 (0.94, 1.71)	1.27 (0.94, 1.71)
Method 3*17	1.09 (0.91, 1.32)	1.09 (0.91, 1.32)	1.09 (0.91, 1.32)
Method 3*18	1.13 (0.90, 1.41)	1.14 (0.91, 1.44)	1.14 (0.91, 1.43)
Grade (ref: 9)			
10		**3.71 (3.23, 4.27)**	**3.71 (3.23, 4.27)**
11		**6.90 (5.79, 8.21)**	**6.90 (5.80, 8.22)**
12		**9.59 (7.66, 2.02)**	**9.61 (7.67, 12.04)**
Sex (ref: female)			
Male		**1.24 (1.12, 1.38)**	**1.24 (1.12, 1.38)**

Table 3.3.1. Continued

	Past-month alcohol use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Race (ref: White)			
Black		**0.33 (0.24, 0.46)**	**0.34 (0.24, 0.46)**
Asian		**0.18 (0.14, 0.23)**	**0.18 (0.14, 0.23)**
Latinx		0.87 (0.62, 1.23)	0.87 (0.62, 1.23)
Other		**0.68 (0.59, 0.79)**	**0.68 (0.59, 0.79)**
Spending Money (ref: $0)			
$1-$20		**2.53 (2.16, 2.97)**	**2.54 (2.16, 2.97)**
$21-$100		**5.91 (4.99, 7.01)**	**5.91 (4.98, 7.00)**
$100+		**11.06 (9.02, 13.57)**	**11.02 (8.98, 13.52)**
Do not know		**2.28 (1.88, 2.77)**	**2.28 (1.88, 2.76)**
Connectedness		**0.92 (0.90, 0.93)**	**0.92 (0.90, 0.93)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.87 (0.54, 1.39)
3rd quartile			1.03 (0.64, 1.65)
4th quartile			0.61 (0.34, 1.08)
Rural (ref: Urban)			
Rural			0.77 (0.47, 1.28)
School Size (ref: Small)			
Medium			**0.60 (0.40, 0.91)**
Large			**0.54 (0.31, 0.93)**
Province			
Alberta			1.93 (0.97, 3.86)
British Columbia			0.66 (0.30, 1.44)

[1] Public health engagement is defined based on method of engagement by the local public health unit. Method 1 is defined as providing information/resources/program. Method 2 is defined as solving problems jointly or developing/implementing program activities jointly. Method 3 is defined as independently running a program at schools to address substance use.
Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table 3.3.2. Association between public health engagement[1] in 2016/17, by method of engagement, and adolescent monthly alcohol binge drinking, over a three-year period from 2016/17 to 2018/19.

	Past-month binge drinking		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.02 (0.02, 0.03)**	**0.02 (0.01, 0.03)**	**0.02 (0.01, 0.05)**
Engagement (ref: None)			
Method 1	0.99 (0.60, 1.65)	1.00 (0.61, 1.64)	1.30 (0.78, 2.15)
Method 2	1.01 (0.51, 1.98)	0.95 (0.50, 1.84)	0.94 (0.49, 1.78)
Method 3	0.84 (0.49, 1.42)	0.83 (0.50, 1.39)	0.99 (0.60, 1.64)
Time (ref: 2016)			
2017	**3.12 (2.68, 3.64)**	**1.50 (1.27, 1.77)**	**1.50 (1.27, 1.77)**
2018	**5.36 (4.45, 6.46)**	**1.79 (1.43, 2.24)**	**1.79 (1.43, 2.24)**
Engagement*year			
Method 1*17	**0.78 (0.63, 0.97)**	**0.77 (0.62, 0.96)**	**0.77 (0.62, 0.96)**
Method 1*18	0.95 (0.73, 1.24)	0.94 (0.72, 1.22)	0.93 (0.72, 1.22)
Method 2*17	1.17 (0.88, 1.57)	1.14 (0.85, 1.52)	1.14 (0.85, 1.52)
Method 2*18	**1.49 (1.06, 2.11)**	**1.45 (1.02, 2.06)**	**1.45 (1.02, 2.05)**
Method 3*17	0.99 (0.79, 1.23)	0.99 (0.79, 1.24)	0.99 (0.79, 1.24)
Method 3*18	1.05 (0.80, 1.37)	1.05 (0.80, 1.37)	1.05 (0.80, 1.37)
Grade (ref: 9)			
10		**4.16 (3.47, 4.99)**	**4.16 (3.47, 4.99)**
11		**7.72 (6.23, 9.57)**	**7.72 (6.23, 9.57)**
12		**10.53 (8.08, 13.71)**	**10.51 (8.07, 13.70)**
Sex (ref: female)			
Male		**1.39 (1.24, 1.56)**	**1.39 (1.24, 1.56)**

Table 3.3.2. Continued

	Past-month binge drinking		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Race (ref: White)			
Black		**0.57 (0.40, 0.82)**	**0.58 (0.40, 0.84)**
Asian		**0.27 (0.20, 0.36)**	**0.28 (0.21, 0.37)**
Latinx		1.11 (0.75, 1.63)	1.11 (0.76, 1.63)
Other		**0.78 (0.66, 0.93)**	**0.78 (0.66, 0.93)**
Spending Money (ref: $0)			
$1-$20		**2.43 (2.02, 2.93)**	**2.44 (2.02, 2.94)**
$21-$100		**5.62 (4.63, 6.82)**	**5.61 (4.62, 6.81)**
$100+		**10.72 (8.56, 13.42)**	**10.67 (8.53, 13.36)**
Do not know		**2.58 (2.06, 3.22)**	**2.57 (2.06, 3.21)**
Connectedness		**0.90 (0.88, 0.92)**	**0.90 (0.89, 0.92)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.90 (0.53, 1.51)
3rd quartile			0.89 (0.53, 1.48)
4th quartile			**0.44 (0.23, 0.85)**
Rural (ref: Urban)			
Rural			0.94 (0.54, 1.62)
School Size (ref: Small)			
Medium			0.64 (0.40, 1.01)
Large			0.59 (0.32, 1.07)
Province			
Alberta			**3.19 (1.48, 6.88)**
British Columbia			0.64 (0.27, 1.52)

[1] Public health engagement is defined based on method of engagement by the local public health unit. Method 1 is defined as providing information/resources/program. Method 2 is defined as solving problems jointly or developing/implementing program activities jointly. Method 3 is defined as independently running a program at schools to address substance use.
Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table 3.3.3. Association between public health engagement[1] in 2016/17, by method of engagement, and adolescent monthly cannabis use, over a three-year period from 2016/17 to 2018/19.

	Past-month cannabis use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.002 (0.001, 0.003)**	**0.04 (0.02, 0.07)**	**0.05 (0.02, 0.10)**
Engagement (ref: None)			
Method 1	0.82 (0.53, 1.26)	0.80 (0.53, 1.20)	0.72 (0.47, 1.10)
Method 2	**0.51 (0.28, 0.93)**	**0.55 (0.31, 0.96)**	**0.43 (0.25, 0.76)**
Method 3	0.94 (0.60, 1.46)	0.91 (0.60, 1.39)	0.84 (0.55, 1.27)
Time (ref: 2016)			
2017	**4.93 (4.00, 6.07)**	**2.05 (1.65, 2.54)**	**2.05 (1.65, 2.54)**
2018	**11.52 (8.97, 14.79)**	**3.25 (2.44, 4.33)**	**3.24 (2.43, 4.31)**
Engagement*year			
Method 1*17	0.98 (0.73, 1.32)	0.96 (0.73, 1.27)	0.96 (0.73, 1.27)
Method 1*18	**1.53 (1.08, 2.15)**	**1.50 (1.08, 2.09)**	**1.51 (1.08, 2.11)**
Method 2*17	1.38 (0.90, 2.11)	1.27 (0.86, 1.89)	1.27 (0.86, 1.89)
Method 2*18	**1.91 (1.17, 3.10)**	**1.81 (1.13, 2.87)**	**1.80 (1.13, 2.86)**
Method 3*17	0.95 (0.71, 1.29)	0.95 (0.71, 1.25)	0.95 (0.71, 1.25)
Method 3*18	1.10 (0.78, 1.55)	1.05 (0.75, 1.47)	1.05 (0.75, 1.46)
Grade (ref: 9)			
10		**5.20 (4.03, 6.70)**	**5.22 (4.04, 6.73)**
11		**9.22 (6.77, 12.55)**	**9.27 (6.81, 12.62)**
12		**13.10 (9.05, 18.96)**	**13.18 (9.11, 19.09)**
Sex (ref: female)			
Male		**2.11 (1.82, 2.46)**	**2.11 (1.82, 2.46)**

Table 3.3.3. Continued.

	Past-month cannabis use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Race (ref: White)			
Black		1.11 (0.73, 1.70)	1.14 (0.75, 1.75)
Asian		**0.21 (0.14, 0.31)**	**0.21 (0.14, 0.32)**
Latinx		1.30 (0.80, 2.11)	1.28 (0.79, 2.08)
Other		**1.54 (1.26, 1.89)**	**1.55 (1.26, 1.90)**
Spending Money (ref: $0)			
$1-$20		**2.06 (1.63, 2.60)**	**2.07 (1.64, 2.62)**
$21-$100		**5.15 (4.04, 6.58)**	**5.17 (4.05, 6.59)**
$100+		**6.80 (5.14, 9.00)**	**6.77 (5.11, 8.96)**
Do not know		**1.55 (1.16, 2.07)**	**1.55 (1.16, 2.08)**
Connectedness		**0.77 (0.75, 0.79)**	**0.77 (0.75, 0.79)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			1.47 (0.99, 2.17)
3rd quartile			0.93 (0.64, 1.37)
4th quartile			0.65 (0.40, 1.05)
Rural (ref: Urban)			
Rural			**0.49 (0.32, 0.75)**
School Size (ref: Small)			
Medium			0.86 (0.60, 1.22)
Large			0.93 (0.59, 1.45)
Province			
Alberta			1.43 (0.79, 2.59)
British Columbia			0.85 (0.45, 1.59)

[1] Public health engagement is defined based on method of engagement by the local public health unit. Method 1 is defined as providing information/resources/program. Method 2 is defined as solving problems jointly or developing/implementing program activities jointly. Method 3 is defined as independently running a program at schools to address substance use.
Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table 3.3.4. Association between public health engagement[1] in 2016/17, by method of engagement, and adolescent monthly cigarette use, over a three-year period from 2016/17 to 2018/19.

	Past-month cigarette use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.004 (0.002, 0.01)**	**0.07 (0.03, 0.14)**	**0.09 (0.04, 0.23)**
Engagement (ref: None)			
Method 1	0.91 (0.42, 1.95)	0.83 (0.41, 1.67)	1.02 (0.54, 1.92)
Method 2	0.67 (0.21, 2.14)	0.71 (0.25, 2.05)	0.65 (0.26, 1.65)
Method 3	0.93 (0.42, 2.08)	0.88 (0.43, 1.80)	1.01 (0.53, 1.93)
Time (ref: 2016)			
2017	**3.63 (2.92, 4.48)**	**2.18 (1.72, 2.75)**	**2.16 (1.72, 2.75)**
2018	**3.67 (2.83, 4.76)**	**1.72 (1.25, 2.36)**	**1.72 (1.25, 2.36)**
Engagement*year			
Method 1*17	0.92 (0.68, 1.26)	0.93 (0.68, 1.26)	0.93 (0.69, 1.27)
Method 1*18	0.86 (0.58, 1.27)	0.88 (0.59, 1.31)	0.88 (0.59, 1.30)
Method 2*17	1.28 (0.81, 2.03)	1.26 (0.79, 1.99)	1.26 (0.79, 1.99)
Method 2*18	1.09 (0.63, 1.90)	1.14 (0.65, 1.97)	1.13 (0.65, 1.97)
Method 3*17	**0.59 (0.44, 0.79)**	**0.59 (0.44, 0.80)**	**0.59 (0.44, 0.80)**
Method 3*18	**0.66 (0.46, 0.96)**	**0.67 (0.46, 0.97)**	**0.67 (0.46, 0.97)**
Grade (ref: 9)			
10		**2.51 (1.97, 3.22)**	**2.53 (1.97, 3.22)**
11		**4.06 (3.00, 5.42)**	**4.06 (3.03, 5.42)**
12		**4.76 (3.29, 6.82)**	**4.76 (3.29, 6.82)**
Sex (ref: female)			
Male		**2.05 (1.73, 2.44)**	**2.05 (1.73, 2.41)**

Table 3.3.4. Continued.

	Past-month cigarette use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Race (ref: White)			
Black		0.81 (0.48, 1.38)	0.84 (0.50, 1.45)
Asian		**0.32 (0.20, 0.50)**	**0.33 (0.21, 0.52)**
Latinx		0.68 (0.36, 1.30)	0.69 (0.36, 1.31)
Other		**1.60 (1.27, 1.99)**	**1.62 (1.28, 2.01)**
Spending Money (ref: $0)			
$1-$20		**2.18 (1.67, 2.83)**	**2.18 (1.67, 2.86)**
$21-$100		**4.44 (3.39, 5.87)**	**4.44 (3.35, 5.81)**
$100+		**5.31 (3.90, 7.17)**	**5.21 (3.86, 7.10)**
Do not know		**1.79 (1.30, 2.48)**	**1.77 (1.28, 2.46)**
Connectedness		**0.77 (0.75, 0.79)**	**0.77 (0.75, 0.79)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			1.52 (0.79, 2.92)
3rd quartile			1.21 (0.60, 2.41)
4th quartile			**0.35 (0.15, 0.86)**
Rural (ref: Urban)			
Rural			1.16 (0.58, 2.34)
School Size (ref: Small)			
Medium			**0.52 (0.29, 0.95)**
Large			**0.30 (0.13, 0.67)**
Province			
Alberta			**4.01 (1.45, 11.13)**
British Columbia			0.78 (0.24, 2.56)

[1] Public health engagement is defined based on method of engagement by the local public health unit. Method 1 is defined as providing information/resources/program. Method 2 is defined as solving problems jointly or developing/implementing program activities jointly. Method 3 is defined as independently running a program at schools to address substance use.
Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table 3.3.5. Association between public health engagement[1] in 2016/17, by method of engagement, and adolescent monthly e-cigarette use, over a three-year period from 2016/17 to 2018/19.

	Past-month e-cigarette use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.01 (0.01, 0.02)**	**0.01 (0.01, 0.02)**	**0.02 (0.01, 0.03)**
Engagement (ref: None)			
Method 1	0.75 (0.47, 1.19)	0.71 (0.46, 1.10)	0.81 (0.53, 1.24)
Method 2	**0.35 (0.17, 0.70)**	**0.35 (0.18, 0.67)**	**0.38 (0.20, 0.72)**
Method 3	0.88 (0.55, 1.39)	0.90 (0.58, 1.39)	0.98 (0.64, 1.49)
Time (ref: 2016)			
2017	**6.69 (5.67, 7.90)**	**5.32 (4.43, 6.38)**	**5.32 (4.43, 6.38)**
2018	**22.30 (18.21, 27.31)**	**16.69 (13.12, 21.23)**	**16.68 (13.11, 21.23)**
Engagement*year			
Method 1*17	**0.74 (0.58, 0.93)**	**0.74 (0.58, 0.94)**	**0.74 (0.59, 0.94)**
Method 1*18	1.17 (0.88, 1.55)	1.19 (0.90, 1.58)	1.19 (0.90, 1.57)
Method 2*17	**2.59 (1.76, 3.82)**	**2.54 (1.73, 3.73)**	**2.54 (1.73, 3.72)**
Method 2*18	**2.63 (1.71, 4.04)**	**2.59 (1.69, 3.97)**	**2.58 (1.69, 3.96)**
Method 3*17	1.04 (0.83, 1.30)	1.04 (0.83, 1.30)	1.04 (0.83, 1.30)
Method 3*18	0.93 (0.72, 1.20)	0.93 (0.72, 1.21)	0.93 (0.72, 1.21)
Grade (ref: 9)			
10		**1.50 (1.26, 1.79)**	**1.50 (1.26, 1.79)**
11		**1.83 (1.48, 2.26)**	**1.83 (1.48, 2.26)**
12		**1.84 (1.42, 2.38)**	**1.84 (1.42, 2.38)**
Sex (ref: female)			
Male		**2.77 (2.46, 3.11)**	**2.77 (2.46, 3.11)**

Table 3.3.5. Continued.

	Past-month e-cigarette use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Race (ref: White)			
Black		**0.64 (0.45, 0.91)**	**0.65 (0.46, 0.92)**
Asian		**0.26 (0.20, 0.34)**	**0.26 (0.19, 0.34)**
Latinx		1.02 (0.70, 1.48)	1.01 (0.70, 1.48)
Other		1.00 (0.85, 1.17)	1.00 (0.85, 1.17)
Spending Money (ref: $0)			
$1-$20		**2.50 (2.10, 2.98)**	**2.51 (2.10, 2.99)**
$21-$100		**5.23 (4.34, 6.31)**	**5.23 (4.34, 6.31)**
$100+		**8.27 (6.63, 10.30)**	**8.24 (6.61, 10.27)**
Do not know		**2.24 (1.81, 2.77)**	**2.24 (1.81, 2.77)**
Connectedness		**0.91 (0.90, 0.93)**	**0.91 (0.90, 0.93)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.81 (0.54, 1.23)
3rd quartile			0.90 (0.57, 1.40)
4th quartile			**0.49 (0.28, 0.85)**
Rural (ref: Urban)			
Rural			0.74 (0.47, 1.17)
School Size (ref: Small)			
Medium			0.98 (0.66, 1.43)
Large			0.83 (0.50, 1.36)
Province			
Alberta			**2.90 (1.51, 5.58)**
British Columbia			1.84 (0.88, 3.86)

[1] Public health engagement is defined based on method of engagement by the local public health unit. Method 1 is defined as providing information/resources/program. Method 2 is defined as solving problems jointly or developing/implementing program activities jointly. Method 3 is defined as independently running a program at schools to address substance use.
Note: **Bold** indicates statistical significance at $p \leq 0.05$

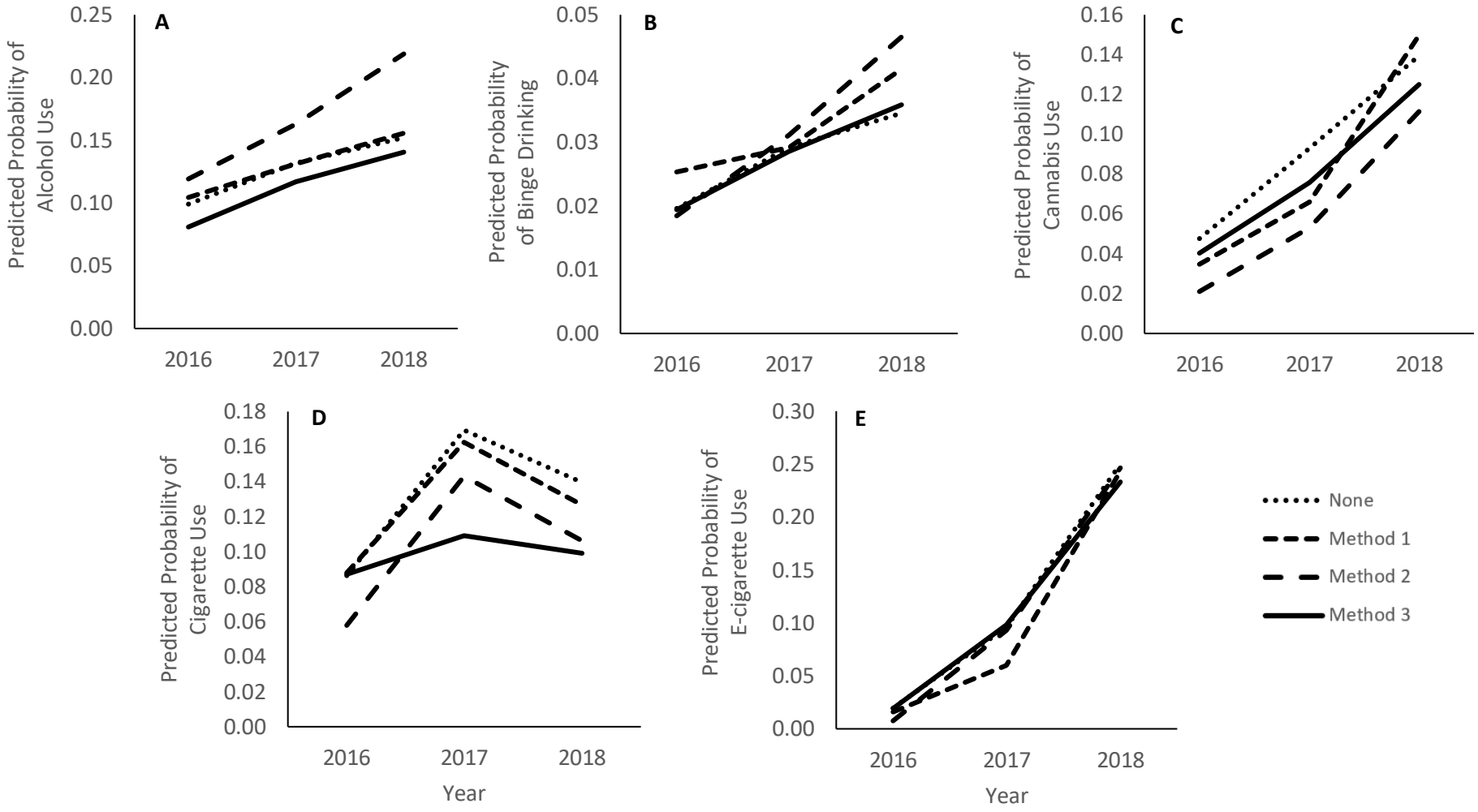

Figure 3.3. Predicted probability of adolescent alcohol use, binge drinking, cannabis use, cigarette use, and e-cigarette use (A-E respectively) by public health unit engagement in COMPASS secondary schools from 2016/17 to 2018/2019. PHU engagement was categorized by four methods of engagement. Method 1 is defined as providing information/resources/program. Method 2 is defined as solving problems jointly or developing/implementing program activities jointly. Method 3 is defined as independently running a program at schools to address substance use.

3.4 Discussion

This study investigated the association between PHU engagement in schools and adolescent substance use over time. Overall, no significant association was observed between PHU engagement and substance use at baseline nor over time.

The first objective of this study was to understand the impact of baseline PHU engagement on substance use over a three-year period. No significant association was found between PHU engagement at baseline and substance use over time when comparing those who were exposed to PHU engagement at baseline with those who were not exposed. These findings were consistent with Burnett et al. (2022), though Burnett et al. conducted a cross-sectional analysis. Although Burnett et al. (2022) found no association between PHU engagement and substance use overall, they did find noteworthy associations after stratifying schools by lower-than-average substance use versus higher-than-average use.[29] In high-use schools, there were some protective associations found against cannabis and cigarette use, lending support for taking a targeted approach. Conversely, in low-use schools, some methods of PHU-engagement were associated with a higher odds of alcohol use and cannabis use. If the association between PHU engagement and substance use in low-use schools is truly the opposite of the associations in high-use schools, this may partly explain the null findings of the present study, where there was no stratification by school prevalence of substance use.

The second objective of this study was to investigate whether different methods of engagement were differently associated with substance use over time. Some associations were observed, depending on substance type. Longitudinally, PHU leadership in running cigarette/e-cigarette use prevention programs was associated with a smaller rise in cigarette use as compared to the absence of any PHU engagement. Though it was not statistically significant, a similar relationship was observed between PHU leadership in running programs to prevent alcohol/cannabis use, and adolescent self-reported cannabis use. Additionally, joint problem solving or program implementation by PHUs and schools was associated with lower odds of cannabis and e-cigarette use at baseline but a larger increase in use over time. These findings are not consistent with Burnett et al. (2022).[29] Burnett et al. (2022) found that PHU engagement in solving problems jointly was associated with higher odds of alcohol and cannabis use, and they found no association between any method of PHU engagement and cigarette or e-cigarette use. The latter finding by Burnett et al. (2022) is also consistent with Vermeer et al. (2021).[26] The

results of this analysis provide evidence that the association between PHU engagement and adolescent substance use depends on the method of engagement chosen and the substance type. When designing collaborative interventions, PHUs and schools may consider which methods have been useful previously and which ones best address school needs.

The null findings of this study are contrary to the protective associations that would be hypothesized. There are many possible explanations for these findings. As illustrated by the socio-ecological and life course models of adolescent health, adolescent substance use is a complex issue and prevention efforts need to consider the context and needs of their target population. While in the case of social drinking, it may be useful to target sports teams and help adolescents build skills in resisting social influence, such a behavioural approach may be ineffective for adolescents engaging in isolated drinking or binge drinking as a means of coping with adverse life events.[15,42–45] Trying cannabis once in the past month, perhaps motivated by peer use, has very different risk factors from daily or solitary cannabis use that may result from a serious underlying issue such as poor mental health or family dysfunction.[15,42] In this study, the binary outcome of past-month substance use can include anything from a single, low-dose use of a given substance to daily, high-dose use. It is unclear whether the impact of PHU engagement would differ by the severity of an individual's substance use. Additionally, the binary outcomes used here do not account for the possibility of using more than one substance simultaneously.[17] This is noteworthy because of the differing risk factors associated with poly-substance use, and therefore the interventions that may be needed from schools and PHUs.[15,17] The findings in this study may be different from previous literature that used data from different years of the COMPASS study, as PHU activities may differ from year to year, due to changes in staff, resources, or protocols. There may also be non-differential misclassification due to variation in PHU activities across schools or jurisdictions, as each PHU operates independently from others.

Of note, this investigation assumes that the resources provided, and programs implemented at schools in this study sample, are in fact effective at preventing or reducing problematic substance use. There has been a vast amount of research over the past 30 years on school-level substance use prevention programs, with evidence varying in quality.[22,44] According to this research, many factors influence the effectiveness of school-based interventions in preventing or reducing substance misuse, including the program content (e.g. lessons in abstinence versus lessons on social influence and norms), the professionals who lead the programs (e.g. school staff versus PHU staff), and the modes of program delivery (e.g. didactic

versus interactive).[43,46] Program types that were associated with positive outcomes more often, though effect size may have been small, were those that helped build personal and social skills (e.g. resilience, self-awareness, self-regulation, empathy, coping with stress), cleared misconceptions around substance use, and aimed to reduce harm rather than creating fear.[23,43,47,48] Delivery styles associated with positive health outcomes, assuming that execution was effective and in line with available evidence, were interactive and participatory.[43,46,49] In fact, involving students in every stage of the process, from intervention design and goal setting to delivery, was found to be particularly effective.[49] There is mixed evidence on effectiveness when evaluating program delivery by external specialists compared to delivery by teaching staff. One suggests that there is greater impact when delivery is by external specialists, while another finds that program delivery by teachers is more effective when teachers are involved in delivery compared to when they are not involved.[47,49] While external specialists such as PHU staff may have greater knowledge and experience in health promotion, teachers are more likely to have a stronger connection and familiarity with their students, along with greater trust built with parents. It was beyond the scope of this study to assess the quality of PHU engagement or the extent to which PHU activities were evidence-informed. It is possible that the null findings in this analysis are a result of some but not all schools and PHUs implementing evidence-informed substance use prevention programs.

3.5 Limitations

A limitation of this study is misclassification due to the broad definition of exposure categories. Although four different types of substances were studied, the study questionnaire inquiring about PHU engagement grouped them into two: PHU engagement to address alcohol OR cannabis use and PHU engagement to address cigarette OR e-cigarette use. Similarly, this study grouped together two methods of engagement: joint problem solving and joint development/implementation of programs. Although this was done to maintain statistical power by minimizing the number of exposure categories, it resulted in a lack of clarity on whether it was problem solving or program implementation, or both, that was associated with substance use. If these two methods had opposing effects on substance use, the resulting association would be biased toward the null.

Another limitation of this work is potential misclassification bias due to the assumption that PHU engagement overall, or by category, looks the same in each school. In other words, it is

assumed that all who have the exposure, have the same exposure. Realistically, the way that PHUs collaborate with schools may vary from the resources they choose to provide and the experience level of PHU staff, to the programs they run. Consequently, the association between exposure and outcome in this study would have been influenced by factors like the type, quality and relevance of PHU engagement - which remains unaccounted for. A poorly designed intervention may increase substance use or diminish any protective impact PHU engagement could otherwise have. This is likely to result in an association that is biased toward the null. Furthermore, the analyses presented here do not consider the time varying nature of PHU engagement. Some schools discontinued collaboration with their local PHU after 2016/17, while others had PHU engagement consistently over the three-year study period. The results shown here do not account for the impact of discontinued or consistent PHU engagement.

Selection bias is likely to have occurred in this study in the form of attrition of students over time. Students may have been lost to follow up due to absence, graduation, changing schools, or their school choosing to withdraw from COMPASS participation.[50] Additionally, there is likely to be missingness related to the study outcome. Those students who use substances often may be more likely to be absent from school, and thus to be absent from school-based surveys.[30,51] One strength of this study that served to reduce selection bias was the active information-passive consent protocol used to recruit students without depending on students to return signed consent forms.

The study results may have been affected by residual confounding due to factors that were unaccounted for in the final regression models. One such factor may be PHU engagement in areas apart from, but related to substance use prevention, such as bullying prevention or addressing mental health. The presence of PHU-run substance use prevention or harm reduction programs in the community but outside of schools may have impacted the study results if these programs also target youth ages 15-19.

Finally, the data for this study were taken from a convenience sample of schools, not necessarily representative of all Canadian secondary schools, resulting in limited external validity. Moreover, those schools that do not participate in the COMPASS study may be different from those that do. It is possible that schools with staff or funding shortages may choose not to participate in COMPASS research due to limited time and capacity.[50]

3.6 Conclusion

This study found no consistent or significant association between PHU engagement in school-based substance use prevention and trends in adolescent alcohol, cannabis, cigarette, or e-cigarette use. However, some significant associations were observed when PHU engagement was analyzed by method of engagement rather than as a binary presence/absence measure. It may be valuable in the future to conduct another longitudinal analysis studying PHU engagement by method of engagement, but with stratification of schools by low versus high substance use, similar to the cross-sectional study by Burnett et al. (2022).[29] Additionally, future research could control for ethnic concentration at the area level, using the Canadian Marginalization Index. Given that both VanderWaal et al. (2006) and McBride et al. (2008) found racial composition to be associated with PHU engagement in schools in the United States, it may be an important confounding variable, or even effect modifier of the association, in a Canadian context as well. It is also recommended that process evaluations be conducted to understand whether or not collaboration is meeting the needs of students, and where gaps may exist, to ensure that the time and resources of PHUs and schools are being optimally utilized to protect and promote adolescent health. Finally, a non-significant difference between schools with and without PHU engagement, namely that a higher proportion of those without PHU engagement are in a rural area or of small enrolment size, is an indicator of potential inequity in PHU engagement. It is recommended that PHUs aim for greater investment of time or resources in schools in a rural area and/or of smaller enrolment size, as they may already have limited resources available for substance use prevention efforts than schools in an urban area or of larger enrolment size.

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CHAPTER 4: PUBLIC HEALTH UNIT PER CAPITA SPENDING AND ADOLESCENT SUBSTANCE USE

4.1 Introduction

In 2019, the prevalence of alcohol and cannabis use in the past year was 46% and 19% respectively among Canadian youth aged 15-19, as reported by the Canadian Alcohol and Drugs Survey.[1] The past-month prevalence of cigarette or electronic cigarette (e-cigarette) use was 5% and 15% respectively, as reported by the Canadian Tobacco and Nicotine survey[2]. Similar patterns of adolescent substance use have been observed in the province of Ontario, Canada. According to the Ontario Student Drug Use and Health Survey, the percentage of youth in grade 9-12 reporting past year use of alcohol, cannabis, cigarette and e-cigarettes in 2019 was 51%, 28%, 7%, and 28% respectively.[3] E-cigarette use more than doubled in only two years among students in grades 7-12, from 10.7% in 2017 to 22.7% in 2019.

The social determinants of health framework (SDOH) is a useful model to use in addressing adolescent substance use.[4] The SDOH framework describes the conditions in which people live, grow, work and age, as well as the structures and systems that shape these conditions.[4] The social determinants include individual, interpersonal, and area level factors as well as the political environment and socioeconomic policies. At the individual and interpersonal levels, personal attitudes and beliefs about substance use, and the attitudes and beliefs of peers and parents, may be predictive of adolescents' use of alcohol, cannabis, cigarettes, or e-cigarettes.[5–7] While a cautious attitude about the social and health consequences of substance use may be protective for some adolescents, a sensation seeking attitude or expectation of a positive experience may increase the likelihood of substance use initiation for other adolescents. Feeling connected with family and school is protective, as is having positive parental support, however having peers or family members who use substances is a risk factor for use.[5,7–10] Among secondary school students, boys, older students, and students with higher weekly spending money have a higher likelihood of substance use.[5,11] Some studies find that non-White race is associated with a lower likelihood of substance use in some age groups.[5,11,12] However, adolescent substance use behaviour is complex. Both protective and risk factors have differing associations with different types of substances and in different contexts of use. For example, Mason et al. (2019) identified distinct risk factors for solitary alcohol/cannabis use as compared to social use.[6] While conformity and expectations of a positive group experience are two risk

factors for social drinking and cannabis use, poor mental health or familial dysfunction are risk factors for solitary, higher-risk use of alcohol or cannabis.[6]

In addition to individual-level and interpersonal risk factors, characteristics of the neighbourhood in which individuals live may also be predictors of substance use. For example, material deprivation, as reflected by low median household income, high unemployment rates, poor housing or a lack of social services have been found in some studies to be risk factors for cigarette and cannabis use.[13–15] However, other studies have found no association between area level deprivation and substance use.[13,16–18] Some studies have found residential mobility to be a risk factor for cigarette use but not alcohol use[18] while others have found it to be protective.[17] Some researchers have found that higher immigrant concentration was associated with reduced alcohol use, but there was no association found between immigrant concentration and other types of substance use.[14,17,19]

Less attention has been given to socioeconomic environments and policies when studying adolescent substance use. Yet, these structural factors may be important in shaping adolescent health directly, or through their impact on individual, interpersonal or area level factors downstream.[20] One such socioeconomic factor that may have an impact on adolescent health outcomes is public health spending. Public health spending is an indicator for investment in public health programs and services.[21,22] McLaughlin and Rank (2018) found that increased federal funding to state health departments was associated with lower infant, neonatal, and post-neonatal mortality rates.[23] At the level of local public health spending, Bernet and colleagues (2018) studied the impact of total public health unit (PHU) spending as well as program-specific spending on infant mortality. They found that total spending was not associated with infant mortality rates, however a 10% increase in infant-related program spending was associated with a 2% decline in infant mortality rates.[24] Conversely, Bekemeier and colleagues (2017) studied program-specific spending on immunizations among toddlers and found no association between spending and immunization coverage.[25] Liu and colleagues studied the impact of public health program spending for children's health on childhood obesity rates and physical activity.[26] They found limited impact of spending on childhood obesity rates. In comparison with the lowest tercile of spending on physical activity, the medium tercile of spending was associated with higher obesity among 4 to 5 year olds. Otherwise, no other level or type of spending was found to be associated with childhood obesity. Another study conducted in England by Paton and Wright (2017) looked at teenage pregnancy. They found that a reduction in local health authority

spending on teenage pregnancy-related services was associated with a lower conception rate, abortion rate, and birth rate among teens.[27] Thus, the findings in the literature are mixed. It appears that the association between spending and child and adolescent health may vary by health outcome of interest, region, age group and/or the type of spending (i.e., program-specific vs total spending).

Some studies have also found a role for PHU spending in reducing health disparities. Bekemeier et al. (2014) found that higher PHU spending was associated with a lower rate of babies born with low birth weight, but only in PHU jurisdictions with the highest under-18 poverty rates.[28] Similarly, higher PHU spending was associated with a lower infant mortality rate in PHU jurisdictions with the highest poverty rate. Bernet et al. (2018 and 2020) found PHU spending to have a role in reducing health disparities by race.[24,29] In one study, a 10% increase in PHU spending on infant-related programs was associated with a 2% decrease in infant mortality rates overall, but a 4% decrease among Black infants specifically. In another study, Bernet and colleagues found that a 10% increase in pregnancy-related PHU spending was associated with a 3.9% reduction in maternal mortality overall, but a 13.5% reduction among Black mothers. These findings suggest that, not only does investment in public health have the potential to improve population health outcomes, but also to bring greater health equity in areas of disparities due to poverty or race.

Research on public health spending and population health has mostly taken place in the United States or Europe. To the best of our knowledge, there are no studies in this area in a Canadian context. The research has largely been in the form of ecological studies, looking at area-level spending and area-level health outcomes. There is limited literature on area-level spending and individual-level health outcomes. Additionally, there have been no studies investigating the association between public health spending and adolescent substance use. However, similar questions have been investigated. A study in the adult population by Friebel and colleagues (2021) found that cuts to government funding for local health authorities in the UK were associated with increased opioid use.[30] Conversely, a £1,000,000 increase in social spending was associated with a decline in opioid-related deaths by 0.017 per 100,000 and opioid-related hospital admissions by 0.4 per 100,000 population. This funding was directed toward social services: social care, housing and planning and development. A similar study in the US that investigated adolescent smoking found that increased state-level funding allocated toward tobacco control was associated with a lower prevalence of adolescent smoking and a lower

quantity of cigarettes smoked daily.[31] In the context of alcohol use, Nilsson et al. (2017) reported that government funding for alcohol prevention programs was associated with more prevention policies and indicators of less frequent alcohol-related harm.[32]

To address gaps in the literature, this study focuses on the association between local public health spending and adolescent past-month use of alcohol, cannabis, cigarettes, or e-cigarettes. Additionally, this study will investigate whether public health spending has a role in reducing health inequities by testing for differences in the spending-substance use association by ethnic composition or material deprivation.

4.2 Methods

4.2.1 Data Source

For this cross-sectional study, data were obtained from the 2018/19 wave of the Cannabis, Obesity, Mental health, Physical activity, Alcohol use, Smoking, and Sedentary behavior (COMPASS) study. The COMPASS study is an ongoing prospective cohort study, aimed at improving adolescent health in multiple domains, including substance use prevention.[33] The COMPASS study collects data from a convenience sample of secondary schools and students in grades 9-12 in Canada. COMPASS data includes a paper-based, student questionnaire (Cq) of demographic information and health indicators that takes approximately 30 minutes to complete. Parents are informed about the details through a letter, voicemail or bulletin page from their child's school, and consent is obtained passively unless parents inform COMPASS staff that they would not like their child to participate. Further details about the COMPASS study and data collection processes can be found online (https://uwaterloo.ca/compass-system/) or in print.[33]

Because exposure information was limited to Ontario, only the Ontario-based COMPASS 2018/19 sample was used for this study. Any students with missing covariate or outcome measures were excluded. This represented 5% of the full sample of 30,675 student in Ontario. The final analytical sample consisted of 29,056 students in grade 9 to 12, attending 61 schools across 15 of Ontario's PHU jurisdictions. Those students with missing outcome data were more likely to be male compared to female, or identify as Black, Asian or Other compared to White (see Appendix I).

4.2.2 Main Exposure

Public health spending was measured as the per capita expenditure in 2018 by Ontario's local public health units. Expenditure data were collected from audited financial statements of each PHU and accessed from the Ontario Public Health Information Database (OPHID). The per capita spending amount was calculated as the total gross expenditure a given PHU made on public health operations in 2018, divided by the health region population in 2018, as estimated by Public Health Ontario. This includes both programmatic and non-programmatic costs, such as salaries and benefits for PHU staff, program supplies, and administrative costs. PHU spending is distinct from spending on public health by state or national governments or private entities. It is also distinct from funding received by public health units for their operations, from municipalities, provincial or federal grants, fees, or other sources.

4.2.3 Main Outcome

The outcome of interest is substance use in the form of current alcohol use, alcohol binge drinking, cannabis use, cigarette use, and e-cigarette use. "Current use" is defined as using at least once in the last 30 days, or at least once per month on average, in accordance with previous literature on substance use.[11,34,35] Binge drinking is defined as having 5 or more drinks of alcohol on one occasion.[3] These indicators were consistent with national substance use surveillance surveys and other studies on adolescent substance use by COMPASS researchers.[1,11,34,36,37]

The frequency of alcohol use was evaluated based on students' response to the question, "*In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?*" Frequency of binge drinking was evaluated based on students' response to the question "*In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?*" Cannabis use was identified from the question *"In the last 12 months, how often did you use marijuana or cannabis? (a joint, pot, weed, hash).*" Response options for all three questions ranged from "*I have never done this*" to "*Daily or almost daily"* or *"Every day.*" Individuals were categorized as being current users if they selected "*once a month*" or any higher frequency. Frequency of cigarette use was determined by the question, "*On how many of the last 30 days did you smoke one or more cigarettes?"* Frequency of e-cigarette use is determined by a subsequent question, "*On how many of the last 30 days did you use a vape?*" Response options for both questions ranged from *"None"* to *"30 days (every day)."* Individuals were categorized as being current users if they selected *"1 day"* or any higher frequency.

4.2.4 Individual Level Covariates

Consistent with other literature by COMPASS researchers, the individual-level characteristics included as covariates in this analysis were sex, grade, race, and spending money. Sex is defined as "female" of "male" and treated as a binary variable. Because adolescent risk behaviours are more likely influenced by gender-based socialization rather than biological differences, any sex differences found will be interpreted as differences due to gender identity.[36,38,39] Grade is a categorical variable defined as one of grade 9, 10, 11, or 12. Students identified their racial identity as being one of the following: White, Black, Asian, Latinx, or Other. Spending money is a categorical variable defined as the amount of money received in a usual week for a student to spend on themselves or to save, from allowance or paid work. The response categories were "$0", "$1 to $20", "$21 to $100", "more than $100", and "I do not know."

4.2.5 School Level Covariates

School-level characteristics included in this analysis were rurality and school enrolment size. Rurality, a binary variable, was determined using the forward sortation area of each school, whereby a 0 in the second digit identifies an area as rural, and urban otherwise.[40] School enrolment size was included as a categorical variable of three levels: small (≤500), medium (501-1000) and large (>1000) similar to previous research by the COMPASS team.[41]

4.2.6 Public Health Unit Level Covariates

At the area level, marginalization scores were included, by PHU jurisdiction, as potential confounders of the association between PHU spending and adolescent substance use. Three marginalization indices used were residential instability, material deprivation, and ethnic concentration. Marginalization scores were obtained from the Ontario Marginalization Index (ON-Marg), made available online by Public Health Ontario.[42] The ON-Marg is derived from the Canadian Marginalization Index which has been validated for use in health research and has demonstrated associations with health outcomes and behaviours.[43] Scores for each index in the ON-Marg are factors constructed using principal component factor analysis from indicators in the Canadian Census.[44] Specifically, residential instability includes the indicators, (1) proportion of population living alone, (2) proportion of population who are not youth (age 5 to 15), (3) average number of persons per dwelling, (4) proportion of dwellings that are apartment

buildings, (5) proportion of population who are single/divorced/widowed, (6) proportion of dwellings not owned, and (7) proportion of population who moved during the past 5 years. Material deprivation includes the following indicators: (1) proportion of population aged 20+ without a high-school diploma, (2) proportion of families who are lone parent families, (3) proportion of total income from government transfer payments for population aged 15+, (4) proportion of population aged 15+ who are unemployed, (5) proportion of population considered low-income, and (6) proportion of households living in dwellings in need of major repair. Ethnic concentration includes the indicators (1) proportion of population who immigrated in the past five years and (2) proportion of population who self-identify as a visible minority.

The indicators making up the 2016 ON-Marg are constructed from the 2016 Canadian Census. There were 36 PHUs in Ontario in 2016 and this number was reduced to 35 in 2018 as two PHUs, Elgin-St. Thomas Health Unit and Oxford County Health Unit were merged into one. As a result, the 2016 ON-Marg index does not perfectly reflect the PHU-level marginalization scores that would have been calculated in 2018, the year of exposure and outcome data in this analysis. To approximate the marginalization score of what would become a merged PHU in 2018, Southwestern Health Unit, weighted average scores were calculated from scores of Elgin-St. Thomas Health Unit and Oxford County Health Unit individually. This calculation was guided by the 2016 ON-Marg User Guide calculation of marginalization score for higher-order geographical units.[44] In reference to the Canadian Marginalization Index, scores from the ON-Marg are standardized with a mean of zero and standard deviation of one, where lower scores correspond to lower levels of marginalization, and higher scores correspond to higher levels of marginalization.[44]

The postal code of each school was used to identify the PHU jurisdiction in which the school was located and to link school level data with PHU spending data. Schools and PHUs were de-identified and saved in the final dataset using only a numerical school ID.

4.2.7 Statistical Analysis

The students in this study were nested within schools, which were nested within PHU jurisdictions. Due to this hierarchical structure, three-level multilevel models (MLM) were used to account for shared characteristics among students in the same school and schools in the same PHU jurisdiction. Level 1 represented the student level data, level 2 represented school level data, and level 3 represented PHU level data. Equations for the three levels of this hierarchically

nested data, when e-cigarette use is the outcome of interest, are shown in Appendix H. Multilevel models, as compared to standard multiple regression, prevent underestimation of the standard error of the estimated regression coefficients. MLM allows for random variation between schools and between PHUs such that information is not lost due to aggregation. Specifically, multilevel logistic regression was used in order to obtain the association between PHU spending per capita and the odds of each binary outcome (current substance use or not).

First, a null model was estimated to calculate the 95% plausible value range of each outcome and to calculate the intraclass correlation coefficient (ICC) at each level (i.e., school and PHU levels). The ICC indicates the percent of variability in outcome that is attributable to school or PHU level factors. Next, individual-, school-, and PHU-level covariates were added to the model to adjust for their effects on adolescent substance use. Finally, interactions were tested between spending and material deprivation, as well as spending and ethnic concentration. A cross-level interaction was also tested between spending and gender as substance use patterns are found in some studies to vary by gender.[36] All analyses were completed using STATA version 17.0 (StataCorp. 2021. *Stata Statistical Software: Release 17*. College Station, TX: StataCorp LLC.)

4.3 Results

Student, school, and area level characteristics are presented in Tables 4.A and 4.B. 49.6% of students identify as female and 66.7% identify as White. The sample consists of 28.2%, 26.9%, 24.2% and 20.7% of students in grades 9, 10, 11 and 12 respectively. 32.8% of schools have an enrolment of 500 or fewer students, 59% of schools have an enrolment of 501 to 1000 students, and 8.2% of schools have an enrolment of more than 1000 students. The mean area-level marginalization scores are below the national average, suggesting that the sample lives in areas of lower marginalization (in the form of residential instability, material deprivation, and ethnic concentration) than the national average. Higher public health spending was significantly associated with lower ethnic concentration, and non-significantly associated with higher material deprivation.

Of the sample, 30.6% are current alcohol users and 17.7% engaged in binge drinking in the past month. 17.4% of students are current cannabis users, 7.8% are current cigarette users, and 30.5% are current e-cigarette users. The 95% plausible value range for alcohol use across PHUs and schools is 20% to 46% and 21% to 45%, respectively. The 95% plausible value range

for binge drinking alcohol across PHUs and schools is 9% to 32% and 10% to 30%, respectively. The 95% plausible value range for cannabis use across both PHUs and schools is 11% to 25%. The 95% plausible value range for cigarette use across PHUs and schools is 3% to 19% and 4% to 15%, respectively. The 95% plausible value range for e-cigarette use across PHUs and schools is 22% to 40% and 20% to 43%, respectively.

The range in annual per capita spending by PHUs in this sample was $54.07 to $224.95, and the median per capita spending amount was $89.62. The mean per capita spending amount was $95.96 (SD: $42.33) indicating a right skewed distribution, likely due to one PHU in the sample spending nearly twice as much per capita amount as the second highest spending PHU, spending $118.80. There were 22 (36%) schools located in a PHU in the lowest quartile of per capita expenditure ($54-$66), 16 (26%) schools located in the second quartile ($68-$90), 12 (20%) schools located in the third quartile ($91-$115), and 11 (18%) schools located in the highest quartile ($117-$225). To test whether there was truly a difference in spending by quartile, on overall chi-square test was conducted. A test statistic of 16.39 and p-value of <0.001 provided evidence for a difference in association between spending and alcohol use, by quartile of spending. A similar test was done for all five study outcomes and a statistically significant result for each test justified the analysis of spending by quartile, for all five outcomes.

Overall, boys, students in higher grades, and students with more weekly spending money all had higher odds of substance use compared to girls, students in lower grades, and students without weekly spending money. School level factors (i.e., school enrolment size and rural/urban location of school) were unrelated to substance use.

When testing for effect modification by material deprivation, there were no significant interactions found. There was a significant interaction between PHU spending and ethnic concentration when investigating the association with alcohol use and alcohol binge drinking. However, not only were the 95% confidence intervals of each interaction term relatively large, the confidence intervals for the main effects of PHU spending categories were much larger than those seen in the fully adjusted models for alcohol use or binge drinking, prior to testing interaction. Thus, the odds ratio estimates were unreliable and effect modification by ethnic concentration was concluded not to be meaningful. Additionally, there was a significant cross-level interaction between PHU spending and gender only for alcohol and alcohol binge drinking. The results of all five analyses are described in detail below, by substance type.

Table 4.1. Sociodemographic characteristics of Ontario students (n=29,056) in the 2018/19 wave of the COMPASS study.

Individual Characteristics	n	%
Gender		
Female	14,401	49.6
Male	14,655	50.4
Race		
White	19,373	66.7
Black	1,832	6.3
Asian	2,548	8.8
Latinx	1,395	4.8
Other	3,908	13.4
Grade		
9	8,196	28.2
10	7,812	26.9
11	7,041	24.2
12	6,007	20.7
Weekly Spending Money		
$0	5,212	17.9
$1-$20	7,039	24.2
$21-$100	6,753	23.2
$100+	6,142	21.1
Do not know	3,910	13.5
School enrolment		
≤ 500	4,798	16.5
501 - 1000	19,838	68.3
>1000	4,420	15.2
Current alcohol user	8,900	30.6
Current binge drinker	5,146	17.7
Current cannabis user	5,045	17.4
Current cigarette user	2,266	7.8
Current e-cigarette user	8,854	30.5

Table 4.2. Characteristics of Ontario schools (n=61) in the 2018/19 wave of the COMPASS study.

School Level	**n**	**%**
School enrolment		
≤ 500	20	32.8
501 - 1000	36	59.0
>1000	5	8.2
Rurality		
Urban	52	85.2
Rural	9	14.8
Area Characteristics	**Mean (SD)**	**Range**
Instability	-0.100 (0.24)	-0.556, 0.294
Deprivation	-0.043 (0.28)	-0.723, 0.378
Ethnic composition	-0.363 (0.50)	-0.858, 0.887

Alcohol Use

The variation in alcohol use that is attributed to between-school differences is 5.2% while the variation attributed to PHU level differences is 2.9%. Unadjusted models indicate a higher odds of alcohol use for adolescents in the third (OR: 1.88; 95% CI: 1.34, 2.64) or fourth (OR: 1.79; 95% CI: 1.23, 2.60) quartile of spending, as compared to the lowest quartile (Table 4.3). The association with the fourth quartile remains statistically significant, though the effect size is reduced, after individual and area level factors are accounted for (AOR: 1.41; 95% CI: 1.04, 1.91). When testing for a cross-level interaction between gender and PHU spending, there is a significant interaction between the two variables, with a significant association between the highest quartile of spending and alcohol use. When other factors are kept constant, boys have a slightly higher odds of alcohol use as compared to girls (OR: 1.10; 95% CI: 1.01, 1.20). However, being in the highest quartile of spending offers a protective interaction with male gender compared to female gender. Among girls alone, those attending school in a PHU jurisdiction in the highest quartile of spending have a 41% higher odds of alcohol use than those attending school in a PHU jurisdiction in the lowest quartile of spending (OR: 1.41; 95% CI: 1.04, 1.91) (Figure 4.1). However, among boys, there is no significant association between

attending school in the highest quartile of spending and the odds of alcohol use (OR: 1.18; 95% CI: 0.87, 1.60). With respect to marginalization, adolescents in more deprived areas (OR: 0.46; 95% CI: 0.26, 0.81) as well as adolescents in area of higher ethnic concentration (OR: 0.53; 95% CI: 0.39, 0.72) have lower odds of alcohol use.

Alcohol Binge Drinking

When investigating binge drinking, the variation that is attributable to between-school differences is 7.4% while the variation attributable to between PHU jurisdictions is 4.1%. Similar to alcohol use generally, unadjusted models indicate a higher odd of binge drinking for adolescents in the third (OR: 1.93; 95% CI: 1.28, 2.90) or fourth (OR: 2.29; 95% CI: 1.45, 3.60) quartile of spending, as compared to the lowest quartile (Table 4.4). These associations remain statistically significant, with a smaller effect size, after accounting for individual level characteristics. However, when area level factors are adjusted for as well, there is a statistically significant association only between the highest quartile of spending and binge drinking (AOR: 1.71; 95% CI: 1.18, 2.48). Additionally, when testing for a cross-level interaction between gender and PHU spending, there is a significant, protective interaction between the highest quartile of spending and male gender. Keeping other factors constant, boys have higher odds of binge drinking as compared to girls (OR: 1.31; 95% CI: 1.18, 1.46). However, among girls alone, those attending school in a PHU jurisdiction in the highest quartile of spending have 71% higher odds of binge drinking alcohol compared to those attending school in a PHU jurisdiction in the lowest quartile of spending (OR: 1.71; 95% CI: 1.18, 2.48) (Figure 4.1). On the other hand, among boys, there is no significant association between attending school in the highest quartile of spending and the odds of binge drinking (OR: 1.30; 95% CI: 0.90, 1.89). Similar to alcohol use generally, living in relatively more deprived areas (OR: 0.37; 95% CI: 0.18, 0.76) or areas of higher ethnic concentration (OR: 0.42; 95% CI: 0.28, 0.62) is associated with a lower odds of binge drinking.

Cannabis Use

The variation in cannabis use that is attributable to between-school differences is 3.6% while the variation attributable to PHU characteristics is 1.9%. Unadjusted models indicate higher odds of cannabis use for adolescents in the fourth quartile of spending, as compared to the lowest quartile (OR: 1.69; 95% CI: 1.35, 2.12) (Table 4.5). This association remains statistically

significant after individual characteristics are accounted for. After adding area level factors however, there remains no statistically significant association between the fourth quartile of PHU spending and adolescent cannabis use (OR: 1.07; 95% CI: 0.83, 1.38). Likewise, there is no significant association between any other quartile of PHU spending and adolescent cannabis use. In the fully adjusted model, boys have a significantly higher odds of cannabis use as compared to girls (OR: 1.41; 95% CI: 1.32, 1.50). With respect to marginalization, adolescents in more deprived areas (OR: 1.69; 95% CI: 1.03, 2.77) have higher odds of cannabis use while adolescents in areas of higher ethnic concentration (OR: 0.56; 95% CI: 0.42, 0.73) have lower odds of cannabis use.

Cigarette Use

The variation in cigarette use that is attributable to between-school differences is 9.8% while the variation attributable to PHU characteristics is 6.6%. Unadjusted models indicate higher odds of cigarette use for adolescents in the third (OR: 2.07; 95% CI: 1.28, 3.34) or fourth (OR: 2.95; 95% CI: 1.72, 5.08) quartile of spending, as compared to the lowest quartile (Table 4.6). These associations remain statistically significant when individual level characteristics are accounted for. After adding area level factors however, there is a statistically significant association only between the highest quartile of spending and the odds of cigarette use. These adolescents have twice the odds of cigarette use as compared to adolescents exposed to the lowest quartile of PHU spending (OR: 2.19; 95% CI: 1.23, 3.91). In the fully adjusted model, boys have higher odds of cigarette use as compared to girls (OR: 1.32; 95% CI: 1.21, 1.45). There were no area level factors associated with cigarette use.

E-cigarette Use

The variation in e-cigarette use that is attributable to between-school differences is 3.7% while the variation attributable to between PHU jurisdictions is 1.3%. Unadjusted models indicate higher odds of e-cigarette use for adolescents in the third (OR: 1.36; 95% CI: 1.00, 1.84) or fourth (OR: 1.67; 95% CI: 1.19, 2.34) quartiles of spending, as compared to the lowest quartile (Table 4.7). The association remains statistically significant only for the fourth quartile after individual characteristics are accounted for. However, when area level factors are added to the model, there remains no statistically significant association between the fourth quartile of PHU spending and adolescent e-cigarette use (OR: 0.99; 95% CI: 0.76, 1.30). Rather, in the fully

adjusted model, the third quartile of PHU spending is associated with adolescent e-cigarette use such that adolescents in the third quartile of spending have a lower odds of e-cigarette use (OR: 0.74; 95% CI: 0.56, 0.98) as compared to adolescents in the lowest quartile of spending. In the fully adjusted model, boys have significantly higher odds of e-cigarette use as compared to girls (OR: 1.33; 95% CI: 1.27, 1.41). As was seen with alcohol and cannabis use, adolescents in areas of higher ethnic concentration have lower odds of e-cigarette use (OR: 0.51; 95% CI: 0.38, 0.68).

Table 4.3. Association between per capita PHU spending and the odds of current alcohol use among grade 9-12 students (n=29,056) in COMPASS schools in Ontario (2018/19).

	Past-month alcohol use			
	Model 1 OR (95% CI)	**Model 2 OR (95% CI)**	**Model 3 OR (95% CI)**	**Model 4 OR (95% CI)**
Constant	**0.33 (0.26, 0.41)**	**0.10 (0.08, 0.12)**	**0.10 (0.07, 0.12)**	**0.09 (0.07, 0.12)**
PHU Spending				
Level 2	1.36 (0.96, 1.92)	1.30 (0.94, 1.79)	1.09 (0.86, 1.38)	1.11 (0.87, 1.42)
Level 3	**1.88 (1.34, 2.64)**	**1.72 (1.25, 2.35)**	1.06 (0.79, 1.42)	1.02 (0.75, 1.38)
Level 4	**1.79 (1.23, 2.60)**	**1.72 (1.21, 2.44)**	1.29 (0.96, 1.72)	**1.41 (1.04, 1.91)**
Gender (ref: female)				
Male		**1.08 (1.02, 1.13)**	**1.08 (1.02, 1.13)**	**1.10 (1.01, 1.20)**
*2nd quartile spending				0.97 (0.85, 1.10)
*3rd quartile spending				1.07 (0.92, 1.25)
*4th quartile spending				**0.84 (0.71, 0.99)**
Race (ref: White)				
Black		**0.77 (0.68, 0.87)**	**0.77 (0.68, 0.87)**	**0.77 (0.68, 0.87)**
Asian		**0.51 (0.46, 0.57)**	**0.51 (0.46, 0.58)**	**0.51 (0.46, 0.58)**
Latinx		0.93 (0.82, 1.06)	0.93 (0.82, 1.06)	0.93 (0.82, 1.06)
Other		**0.91 (0.84, 0.99)**	**0.91 (0.84, 0.99)**	**0.91 (0.84, 0.99)**
Grade (ref: 9)				
10		**1.75 (1.62, 1.90)**	**1.76 (1.62, 1.90)**	**1.76 (1.62, 1.90)**
11		**2.42 (2.24, 2.62)**	**2.42 (2.24, 2.62)**	**2.42 (2.24, 2.63)**
12		**3.04 (2.80, 3.30)**	**3.04 (2.80, 3.30)**	**3.04 (2.80, 3.30)**
Personal Spending Money (ref: $0)				
$1-$20		**1.47 (1.34, 1.62)**	**1.47 (1.34, 1.62)**	**1.47 (1.34, 1.62)**
$21-$100		**2.52 (2.30, 2.75)**	**2.52 (2.30, 2.76)**	**2.52 (2.30, 2.76)**
$100+		**3.34 (3.05, 3.66)**	**3.34 (3.04, 3.66)**	**3.34 (3.05, 3.66)**
Do not know		**1.47 (1.32, 1.63)**	**1.47 (1.32, 1.64)**	**1.47 (1.32, 1.63)**

Table 4.3. Continued.

	Past-month alcohol use			
Variable	**Model 1 OR (95% CI)**	**Model 2 OR (95% CI)**	**Model 3 OR (95% CI)**	**Model 4 OR (95% CI)**
Schoolsize (ref: Small)				
Medium			0.92 (0.77, 1.11)	0.92 (0.74, 1.17)
Large			0.89 (0.66, 1.19)	0.89 (0.68, 1.43)
Instability			0.97 (0.55, 1.70)	0.97 (0.55, 1.70)
Deprivation			**0.47 (0.27, 0.84)**	**0.47 (0.27, 0.84)**
Ethnic concentration			**0.52 (0.38, 0.71)**	**0.52 (0.38, 0.71)**
Rurality (ref: urban)				
Rural			1.12 (0.89, 1.41)	1.12 (0.89, 1.41)

Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table 4.4. Association between per capita PHU spending and the odds of current binge drinking among grade 9-12 students (n=29,056) in COMPASS schools in Ontario (2018/19).

	Past-month binge drinking			
	Model 1 OR (95% CI)	**Model 2 OR (95% CI)**	**Model 3 OR (95% CI)**	**Model 4 OR (95% CI)**
Constant	**0.14 (0.11, 0.19)**	**0.03 (0.03, 0.05)**	**0.03 (0.02, 0.04)**	**0.03 (0.02, 0.04)**
PHU Spending				
Level 2	1.41 (0.93, 2.13)	1.33 (0.89, 1.99)	1.02 (0.76, 1.37)	1.08 (0.80, 1.47)
Level 3	**1.93 (1.28, 2.90)**	**1.80 (1.22, 2.66)**	0.94 (0.66, 1.36)	0.92 (0.63, 1.34)
Level 4	**2.29 (1.45, 3.60)**	**2.25 (1.46, 3.47)**	**1.48 (1.03, 2.12)**	**1.71 (1.18, 2.48)**
Gender (ref: female)				
Male		**1.23 (1.15, 1.31)**	**1.23 (1.15, 1.31)**	**1.31 (1.18, 1.46)**
*2nd quartile spending				0.90 (0.77, 1.05)
*3rd quartile spending				1.05 (0.87, 1.26)
*4th quartile spending				**0.76 (0.63, 0.93)**
Race (ref: White)				
Black		1.04 (0.90, 1.20)	1.04 (0.90, 1.20)	1.04 (0.90, 1.20)
Asian		**0.62 (0.53, 0.71)**	**0.62 (0.53, 0.71)**	**0.62 (0.53, 0.71)**
Latinx		1.11 (0.95, 1.30)	1.11 (0.95, 1.29)	1.11 (0.95, 1.29)
Other		1.09 (0.99, 1.20)	1.09 (0.99, 1.20)	1.09 (0.99, 1.20)
Grade (ref: 9)				
10		**1.95 (1.76, 2.16)**	**1.95 (1.76, 2.16)**	**1.95 (1.76, 2.16)**
11		**2.70 (2.44, 2.99)**	**2.70 (2.44, 2.99)**	**2.70 (2.44, 2.99)**
12		**3.63 (3.27, 4.03)**	**3.64 (3.28, 4.03)**	**3.64 (3.28, 4.04)**
Personal Spending Money (ref: $0)				
$1-$20		**1.33 (1.17, 1.50)**	**1.33 (1.18, 1.50)**	**1.33 (1.17, 1.50)**
$21-$100		**2.30 (2.05, 2.58)**	**2.30 (2.05, 2.58)**	**2.30 (2.05, 2.58)**
$100+		**3.22 (2.87, 3.60)**	**3.22 (2.87, 3.61)**	**3.22 (2.88, 3.61)**
Do not know		**1.34 (1.16, 1.53)**	**1.34 (1.17, 1.53)**	**1.33 (1.16, 1.53)**

Table 4.4. Continued.

	Past-month binge drinking			
	Model 1 OR (95% CI)	**Model 2 OR (95% CI)**	**Model 3 OR (95% CI)**	**Model 4 OR (95% CI)**
Schoolsize (ref: Small)				
Medium			0.93 (0.74, 1.17)	0.93 (0.74, 1.17)
Large			0.99 (0.68, 1.43)	0.99 (0.68, 1.43)
Instability			1.24 (0.61, 2.52)	1.24 (0.61, 2.51)
Deprivation			**0.37 (0.18, 0.76)**	**0.37 (0.18, 0.76)**
Ethnic concentration			**0.42 (0.28, 0.62)**	**0.42 (0.28, 0.62)**
Rurality (ref: urban)				
Rural			1.19 (0.89, 1.57)	1.19 (0.90, 1.57)

Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table 4.5. Association between per capita PHU spending and the odds of current cannabis use among grade 9-12 students (n=29,056) in COMPASS schools in Ontario (2018/19).

	Past-month cannabis use		
	Model 1 OR (95% CI)	**Model 2 OR (95% CI)**	**Model 3 OR (95% CI)**
Constant	**0.19 (0.16, 0.21)**	**0.04 (0.04, 0.05)**	**0.04 (0.03, 0.05)**
PHU Spending			
Level 2	1.06 (0.87, 1.28)	1.02 (0.85, 1.24)	0.95 (0.77, 1.16)
Level 3	1.14 (0.92, 1.41)	1.10 (0.89, 1.36)	0.82 (0.63, 1.06)
Level 4	**1.69 (1.35, 2.12)**	**1.58 (1.26, 1.97)**	1.07 (0.83, 1.38)
Gender (ref: female)			
Male		**1.41 (1.32, 1.50)**	**1.41 (1.32, 1.50)**
Race (ref: White)			
Black		**1.62 (1.43, 1.84)**	**1.64 (1.45, 1.86)**
Asian		**0.63 (0.55, 0.73)**	**0.64 (0.56, 0.74)**
Latinx		**1.20 (1.03, 1.39)**	**1.20 (1.03, 1.40)**
Other		**1.56 (1.43, 1.71)**	**1.57 (1.44, 1.72)**
Grade (ref: 9)			
10		**1.83 (1.65, 2.02)**	**1.83 (1.65, 2.02)**
11		**2.33 (2.11, 2.58)**	**2.34 (2.12, 2.59)**
12		**3.02 (2.72, 3.34)**	**3.03 (2.73, 3.35)**
Personal Spending			
Money (ref: $0)			
$1-$20		**1.35 (1.20, 1.52)**	**1.35 (1.20, 1.52)**
$21-$100		**2.08 (1.86, 2.33)**	**2.08 (1.86, 2.32)**
$100+		**2.79 (2.49, 3.11)**	**2.78 (2.49, 3.10)**
Do not know		**1.30 (1.14, 1.48)**	**1.30 (1.14, 1.48)**
Schoolsize (ref: Small)			
Medium			1.00 (0.85, 1.18)
Large			0.96 (0.74, 1.24)

Table 4.5. Continued.

	Past-month cannabis use		
	Model 1 OR (95% CI)	**Model 2 OR (95% CI)**	**Model 3 OR (95% CI)**
Instability			0.74 (0.45, 1.22)
Deprivation			**1.69 (1.03, 2.77)**
Ethnic concentration			**0.56 (0.42, 0.73)**
Rurality (ref: urban)			
Rural			0.86 (0.70, 1.05)

Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table 4.6. Association between per capita PHU spending and the odds of current cigarette use among grade 9-12 students (n=29,056) in COMPASS schools in Ontario (2018/19).

	Past-month cigarette use		
	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Constant	**0.06 (0.04, 0.08)**	**0.02 (0.01, 0.03)**	**0.02 (0.01, 0.03)**
PHU Spending			
Level 2	1.19 (0.74, 1.93)	1.18 (0.73, 1.93)	1.16 (0.70, 1.91)
Level 3	**2.07 (1.28, 3.34)**	**2.14 (1.31, 3.49)**	1.46 (0.77, 2.77)
Level 4	**2.95 (1.72, 5.08)**	**2.78 (1.60, 4.82)**	**2.19 (1.23, 3.91)**
Gender (ref: female)			
Male		**1.32 (1.21, 1.45)**	**1.32 (1.21, 1.45)**
Race (ref: White)			
Black		**1.99 (1.67, 2.38)**	**2.00 (1.67, 2.39)**
Asian		0.86 (0.70, 1.06)	0.86 (0.70, 1.06)
Latinx		**1.32 (1.05, 1.65)**	**1.32 (1.06, 1.66)**
Other		**2.04 (1.81, 2.29)**	**2.04 (1.81, 2.29)**
Grade (ref: 9)			
10		**1.47 (1.28, 1.69)**	**1.47 (1.28, 1.69)**
11		**1.87 (1.63, 2.15)**	**1.87 (1.63, 2.15)**
12		**2.62 (2.28, 3.01)**	**2.63 (2.29, 3.02)**
Personal Spending Money (ref: $0)			
$1-$20		**1.19 (1.01, 1.40)**	**1.19 (1.01, 1.40)**
$21-$100		**1.45 (1.24, 1.70)**	**1.45 (1.24, 1.70)**
$100+		**2.14 (1.84, 2.49)**	**2.14 (1.84, 2.49)**
Do not know		1.08 (0.90, 1.31)	1.08 (0.90, 1.31)
Schoolsize (ref: Small)			
Medium			0.81 (0.60, 1.11)
Large			0.64 (0.40, 1.02)

Table 4.6. Continued.

	Past-month cigarette use		
	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Instability			0.76 (0.23, 2.47)
Deprivation			0.86 (0.27, 2.74)
Ethnic concentration			0.62 (0.32, 1.20)
Rurality (ref: urban)			
Rural			1.09 (0.79, 1.52)

Note: **Bold** indicates statistical significance at p≤0.05

Table 4.7. Association between per capita PHU spending and the odds of current e-cigarette use among grade 9-12 students (n=29,056) in COMPASS schools in Ontario (2018/19).

	Past-month e-cigarette use		
	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Constant	**0.34 (0.28, 0.42)**	**0.12 (0.10, 0.15)**	**0.12 (0.10, 0.15)**
PHU Spending			
Level 2	1.34 (0.99, 1.80)	1.30 (0.99, 1.69)	1.05 (0.84, 1.31)
Level 3	**1.36 (1.00, 1.84)**	1.22 (0.93, 1.60)	**0.74 (0.56, 0.98)**
Level 4	**1.67 (1.19, 2.34)**	**1.56 (1.16, 2.12)**	0.99 (0.76, 1.30)
Gender (ref: female)			
Male		**1.33 (1.27, 1.41)**	**1.33 (1.27, 1.41)**
Race (ref: White)			
Black		0.91 (0.81, 1.02)	0.91 (0.81, 1.02)
Asian		**0.57 (0.51, 0.64)**	**0.58 (0.51, 0.64)**
Latinx		1.09 (0.96, 1.23)	1.09 (0.96, 1.23)
Other		1.05 (0.97, 1.14)	1.05 (0.97, 1.14)
Grade (ref: 9)			
10		**1.46 (1.36, 1.57)**	**1.46 (1.36, 1.57)**
11		**1.53 (1.42, 1.65)**	**1.53 (1.42, 1.66)**
12		**1.62 (1.49, 1.75)**	**1.62 (1.50, 1.76)**
Personal Spending			
Money (ref: $0)			
$1-$20		**1.53 (1.40, 1.68)**	**1.53 (1.40, 1.68)**
$21-$100		**2.45 (2.24, 2.67)**	**2.45 (2.24, 2.67)**
$100+		**3.24 (2.96, 3.55)**	**3.23 (2.95, 3.54)**
Do not know		**1.40 (1.26, 1.55)**	**1.40 (1.26, 1.55)**
Schoolsize (ref: Small)			
Medium			0.98 (0.82, 1.16)
Large			0.90 (0.68, 1.19)

Table 4.7. Continued.

	Past-month e-cigarette use		
	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Instability			1.23 (0.72, 2.10)
Deprivation			0.76 (0.45, 1.30)
Ethnic concentration			**0.51 (0.38, 0.68)**
Rurality (ref: urban)			
Rural			1.08 (0.87, 1.34)

Note: **Bold** indicates statistical significance at p≤0.05

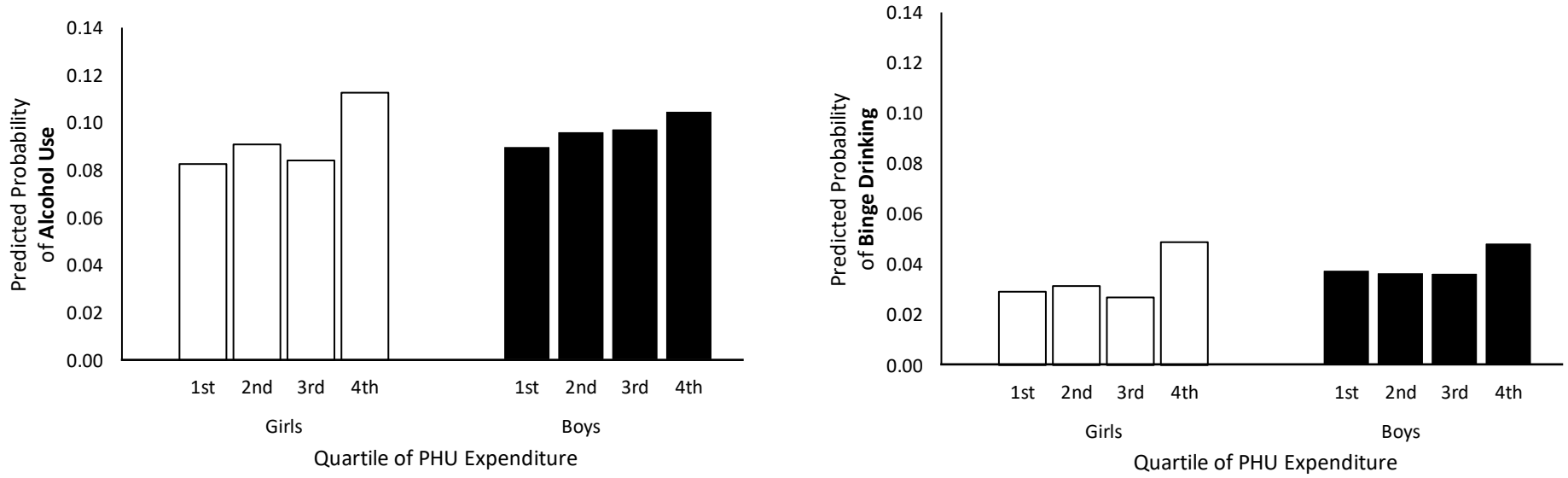

Figure 4.1. Probability of adolescent alcohol use (left) and binge drinking (right) in COMPASS secondary schools in 2018/19, as predicted by per capita public health unit expenditure and stratified by gender.

4.4 Discussion

To our knowledge, this is the first study to investigate the association between public health unit spending per capita and adolescent substance use. The results show that, relative to the lowest quartile of PHU spending per capita, adolescents attending school in an area with the highest quartile of spending per capita have higher odds of alcohol use generally, alcohol binge drinking, and cigarette use. Public health unit spending per capita is not associated with cannabis use. With respect to e-cigarette use, adolescents attending school in an area with the second highest quartile of PHU spending per capita have lower odds of e-cigarette use than those attending school in the lowest quartile of PHU spending.

Previous research exists on the relationship between public health spending and various health outcomes, however the mechanisms by which public health spending influences health outcomes is unclear. Pathways by which such an association might occur have been proposed. The Donabedian model of health services research describes "structure," "process" and "outcome" characteristics in evaluating health care quality.[45] Adapting this model to a public health context, Meyer et al. (2012) propose a conceptual framework that offers a potential pathway from PHU spending to population health outcomes.[46] According to their model, financial resources are a component of organizational capacity, among other measures, such as human and information resources. Improved organizational capacity is hypothesized to lead to improved system performance, defined as the internal processes of a public health department that allow for disease prevention and health promotion activities, such as preventing adolescent substance use.[21,47] A robust public health system may subsequently lead to improved population health outcomes, such as reduced morbidity and mortality or improved health-related knowledge and behaviour.[46] There is evidence that increased funding can, at least in some contexts, improve public health system performance.[48,49] Erwin and colleagues (2011) propose mechanisms by which spending and system performance may be associated.[50] They suggest that improved outcomes in the area of communicable diseases may be due to funding-associated capacity for increased surveillance and epidemiological studies, while improvements in the area of noncommunicable disease may be due to risk factor mitigation through screening or interventions such as those addressing cholesterol levels and health behaviors like smoking and higher-risk substance use. Similarly, findings by Bernet and colleagues demonstrate that targeted public health spending on maternal and child health programs is associated with improved

maternal mortality and infant mortality respectively, especially for historically disadvantaged Black populations.[24] As Mays and colleagues point out, this may not apply to all services, and it may depend where the funding is received from (federal, state-level, or local revenue source), as there may be limitations placed on how federal funds can be used as compared to municipal funds that may have fewer restrictions.[49,51] Institutional and community characteristics, such as local poverty level, physician-to-population ratio, centralized or decentralized structure of public health administration, or partnerships between community organizations, are also important factors to consider.[51,52]

On the other hand, as noted by Singh (2014), increased funding for public health does not guarantee improved performance of a public health organization, nor does improved performance guarantee better health outcomes.[21] In their systematic review on this topic, Singh (2014) reports mixed evidence on the association between public health system performance and population health. Some studies are reported to have found a protective association between system performance and health status, at least one found no difference between high and low performance systems, while yet another found that higher system performance was associated with adverse health status. This mixed evidence may be due to other factors at play, such as governance. Although they studied public spending on health generally rather than public health services, two studies on public spending find that the effect of governance quality (e.g. honest and transparent budget distribution) is important.[53,54] Hu and Mendoza (2013) found that public spending is significantly associated with infant mortality even when controlling for governance quality, while Rajkumar and Swaroop (2008) found that public spending is significantly associated with infant mortality in countries with good quality governance, but has little impact on infant mortality when governance is of poor quality.

Improved public health processes and programs may offer a pathway by which public health spending is associated with population health outcomes. However, it is also possible that public health spending itself is an independent predictor of population health. Kentikelenis (2017) as well as Stuckler and colleagues (2017) describe how austerity policies, as a form of "structural adjustment", can impact health outcomes by addressing the social determinants of health, such as employment, poverty, and inequality.[55,56] There is substantial evidence showing that increased unemployment, poverty and inequalities impact individual health and behaviour.[57–59] Increased PHU spending may be associated with public health activities that target adolescents

directly or that impact the social determinants of health. In Ontario, it is a requirement for PHUs to develop and implement programs to promote the health of adolescents, and to offer support to schools in implementing health-related curricula in areas such as healthy sexuality, mental health promotion, substance use, substance-related harm reduction, violence and bullying.

4.5 Limitations

One limitation of this study is that it was cross-sectional in design and thus did not allow for time between exposure and outcome. This is a limitation because, where public health spending is associated with improved population health outcomes, there is likely to be a lag between spending and any measurable impact.[29,60,61] In the case of spending for direct prevention or harm reduction programming, we may expect to see an impact on adolescents in the shorter term in the form of delayed onset of substance use or less risky patterns of use among current users.[28,62] Conversely, public health spending for more upstream initiatives, such as policy change, may not have an impact on adolescent risk behaviour for a longer period of time. One study looking at public health spending and mortality rates estimates that though spending may impact mortality rates in the short term of one year, the majority of the impact is seen 8-10 years following a change in PHU spending.[60]

Another limitation of a cross-sectional study design is that, because it does not allow for temporality between the exposure and outcome, there is no evidence that the hypothesized exposure, PHU spending, precedes the hypothesized outcome, adolescent substance use. It is unclear whether greater spending in a given PHU jurisdiction is a response to, or a risk factor for poor adolescent health behaviours. Higher odds of adolescent alcohol and cigarette use may be an indicator of poor access to the social determinants of health to which PHUs may respond with more programs and spending.

Residual confounding is a limitation of this study. It describes an association between the study exposure as well as the study outcome with a third variable that was unaccounted for. Among potential confounders of the association between spending and substance use, one might be social service spending. Given the numerous social determinants of adolescent substance use discussed previously, social service spending, or a lack of sufficient social service spending, could have a significant impact on adolescent substance use. By addressing such upstream factors as unemployment, poverty, housing insecurity or low educational attainment, social

services have the potential to improve the social and familial environments that adolescents grow up in and reduce the likelihood of substance use.[5,7,9,22] At the same time, government funding available for PHUs may be impacted by the level of funding allocated to social services outside of PHU activities.[63]

Another important limitation of this study is selection bias in the form of missingness. It has been shown that adolescent substance use is associated with school absenteeism and those students who were absent would not have been able to complete the COMPASS student questionnaire.[33,64]

There is also a possibility of information bias in the exposure measure. Audited financial statements were unavailable for two of fifteen PHUs and alternative sources of expenditure data had to be used, such as PHU annual reports or budget plans that were available online. Although these reports are expected to provide reasonable estimates of expenditure, there is a possibility of variation from the actual expenditure. Additionally, there is potential misclassification of the study outcomes. Past-month substance use could be wide ranging, from once in a month to daily, or even multiple times a day. The survey question does not reveal the amount or dose that was used. This means that substance use in any amount or frequency was treated equally, so long as it occurred at least once per month on average or once in the past month specifically. This misclassification would miss the differential impact that PHU spending may have on higher frequency, and thus higher-risk users, as compared to occasional users. Prevention programs that address risk factors of substance use such as poor mental health or low school connectedness may have more impact on higher-risk users as compared to adolescents using less frequently and with different motivations, such as peer-use at social events.[6]

Finally, this study has limited external validity given that school selection in the COMPASS study uses convenience sampling. The study results are not generalizable to a population outside of the COMPASS schools in Ontario.

4.6 Conclusion

This study presents mixed findings on the association between PHU spending and adolescent substance use. In the case of alcohol and cigarette use, adolescents in the highest quartile of PHU spending had higher odds of use as compared to adolescents in the lowest quartile. However, because this is a cross-sectional study, temporality could not be identified between PHU spending and the substance use outcomes. Future research could take a

longitudinal approach by studying substance use outcomes in the years following expenditure measures to allow for temporality between exposure and outcome. Additionally, future analyses may be made more robust by studying a larger sample of PHUs for improved statistical power.[24,60] Future studies may also find more meaningful associations by distinguishing occasional substance use in the past month from higher-frequency and higher-risk patterns of substance use, such as weekly use, daily use, or use while alone. Given the dearth of literature in a Canadian setting, further research on public health spending and adolescent health outcomes in Canada may allow for evidence-informed decisions on the optimal allocation of limited financial resources to better protect and promote adolescent health.

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CHAPTER 5: CONCLUSION

The aim of this thesis was to investigate the role of public health units in addressing adolescents' use of alcohol, cannabis, cigarettes, and e-cigarettes. Multilevel regression models were used for all analyses due to the clustering of observations by student for each year of their survey participation, the clustering of students within schools, and the clustering of schools within PHU jurisdictions.

The first research objective was to investigate the association between public health engagement at schools and the three-year trend in adolescent substance use. To meet this objective, there were two research questions examined. The first question asked whether any PHU engagement at baseline was associated with substance use over a three-year period. The second question asked whether different methods of PHU engagement at baseline had differing associations with substance use over a three-year period. Specifically, PHUs could be engaged with secondary schools through resource provision, joint problem solving, and joint program development/implementation, or independent program implementation. In the case of binge drinking and e-cigarette use, PHU provision of information and resources appeared to be protective over time, reducing the odds of use in the following years. Joint problem solving or joint program implementation, though protective at baseline, was associated with more binge drinking and e-cigarette use, as well as more cannabis use, by the second follow up year. This is not a finding that was expected. Further investigation is recommended to understand whether problem solving, or the selected programs of intervention were ineffective, or if other factors were at play. In the case of cigarette use only, a PHU-led substance use prevention program at baseline was associated with lower odds of cigarette use in the two subsequent years. These findings suggest that the association between PHU engagement and substance use varies by the method of PHU engagement and type of substance use. Looking at engagement overall may result in non-significant findings due to different methods influencing adolescent substance use in different directions. Moreover, the analysis of different methods of engagement at baseline did not take into account the change in PHU engagement over time, so it could be that the longitudinal association was a result not of baseline engagement, but a change in PHU activities over time, including potential discontinuation of PHU engagement.

There are other limitations to make note of as well. For one, the COMPASS SPP survey questions on PHU engagement asked about two substances at a time: PHU engagement to

address alcohol OR cannabis use and PHU engagement to address cigarette OR e-cigarette use. One extreme consequence of this categorization is the possibility that a school may provide resources, programming or problem solving focused only on one of the two. For example, if PHU engagement is focused primarily on alcohol-related intervention, it is unlikely to impact cannabis use by any direct pathway, particularly given that the risk factors for, motivations for, and contexts of alcohol and cannabis use can be quite different, and it may be incorrect to attribute changes in cannabis use to an alcohol-focused intervention.[1] The same applies to the survey question inquiring about PHU engagement in addressing cigarette and e-cigarette use. Many factors distinguish each of these substances, including the background trends in use or the social acceptability of each. For example, alcohol use is more prevalent and socially acceptable than cannabis, cigarette or e-cigarette use.[2,3] However, new vaping products, particularly with different and appealing flavours, have led to significant increases in use by youth.[4] Meanwhile, years of tobacco prevention and control interventions and education campaigns are associated with a declining trend in cigarette smoking.[2,5,6]

Second, two methods of engagement were grouped into one when answering the second research question. These were joint problem solving and joint development/implementation of programs. In fact, the SPP survey allows for respondents to select more than one level of PHU engagement, so there may have been cases of misclassification whereby a PHU was involved in multiple forms of engagement, but only identified as having one – the highest selected method of engagement. As none of the methods of engagement were mutually exclusive, the impact of engagement may have been a result of a combination of methods employed. Furthermore, two different methods of engagement may complement each other in a positive way, or negative way. If staff and resources were well-coordinated, they may have had a greater impact in combination. Alternatively, if staff or resources were limited and divided, each individual method may have been compromised.

Future research is warranted in this area to better understand how the method of PHU engagement affects different types of substance use, so that PHU resources can be optimally allocated to schools. This study offers a starting point for such future investigation. Findings from this study suggest that it may be beneficial for PHUs to invest in the provision of information/resources/programs and in PHU-led programs at secondary schools, to address adolescent substance use – particularly binge drinking, cigarette use, and e-cigarette use.

Collaboration with schools may also be a valuable opportunity for public health to address other school-related factors associated with substance use. Namely, peer substance use, low school connectedness, low educational expectations and school disengagement are risk factors for adolescent substance use.[7] Outside of schools, public health activities that may impact adolescent risk behaviour indirectly include policy promotion to reduce youth access to tobacco products and e-cigarettes and programming in the area of healthy growth and development to support healthy families.[8] Such activities are important given that healthy public policy and supportive parenting are significant protective factors against adolescent substance use.[7,9–11] Public health activities also include those which address other social determinants that, due to structural disadvantage, are associated with adolescent substance use. These social determinants include low income, housing insecurity, and low educational attainment.[12–14] In Ontario, it is provincially mandated in the Ontario Public Health Standards that each PHU address social determinants of health to improve health equity. One means of affecting structural change and improving access to the social determinants of health might be through increased spending on public health.

The second research objective was to study spending by PHUs as an indicator of financial investment into public health. Specifically, the objective was to investigate the association between per capita expenditure by PHUs and adolescent substance use. Overall, there was little association between PHU spending and adolescent substance use. However, higher quartiles of PHU spending, relative to the lowest quartile, were found to be associated with higher odds of alcohol and cigarette use, and lower odds of e-cigarette use. This finding may be a reflection of resource allocation based on need. Although PHU spending decisions are not made based on adolescent substance use alone, if at all, it is possible that adolescent substance use is correlated with other adolescent health/safety needs.[3] Reszycynski et al. (2022) conducted a study in the United States to investigate whether PHU spending decisions are a response to local context by using sociodemographic variables such as race, unemployment and poverty as indicators of public health need.[15] In the case of the United States, Reszycynski found that spending was not necessarily increased in areas of greater need. However, in the present study, there is no evidence to infer a causal association in either direction. It would indeed be expected and is a possibility that spending was higher where population need was greater, such as areas of higher adolescent substance use.

A limitation of this study is the small sample size of PHUs. This analysis used a three-level multilevel regression model that accounts for clustering at the school and PHU levels. In a multilevel model, two important factors that impact statistical power are the intraclass correlation (ICC) and sample size at the highest level of analysis – in this case, the sample of PHUs. Unfortunately, there are only 15 Ontario PHUs represented in the 2018 COMPASS sample. According to a simulation study of two-level models by Maas and Hox (2005), a sample size of 50 groups was recommended for the higher-level unit of analysis to minimize bias in the estimation of regression coefficients.[17] 15 PHUs is much smaller than the recommended 50, and this may mean that the present study lacks power to detect an association between PHU level spending and individual level substance use behaviour. Nevertheless, it was important to use three levels of analysis rather than two because of the nested data structure and because the exposure of interest occurs at the level of PHU jurisdictions, the highest level of clustering. The assumption of independence of observations required for multiple regression analyses would be violated if clustering were unaccounted for. Additionally, the results from these studies are not necessarily reflective of the general population as the COMPASS data used here are taken from a convenience sample of students and schools. Furthermore, in the case of the spending study, only around 40% of all Ontario PHUs are represented.

Despite the limitations, both studies have some important strengths as well. Both use participant data from the COMPASS study, which offers a large sample size of students that is otherwise challenging to recruit. Though it may not be reflective of all Canadian adolescents, it is likely representative of a large portion. The study on public health engagement is the first to take a longitudinal approach in investigating this topic to understand the association between PHU activities and adolescent substance use over time. The second study is the first known study to investigate public health spending and adolescent substance use. To the best of our knowledge, it is the only study of PHU spending and adolescent health outcomes to be conducted in a Canadian context. It is also the first to investigate PHU-level spending and individual-level outcomes rather than health outcomes aggregated to the area level. In future research, a longitudinal study design may help to better understand the associations found in the present study by allowing for temporality between exposure (spending) and outcome (substance use). Such research would allow for evidence-informed policy decisions on public health spending, particularly in times of austerity when financial resources are limited and must be effectively

distributed. Research on public health spending in a Canadian setting can ensure evidence that is applicable to Canadians.

Both studies conducted in this thesis offer insights on the role of PHUs in addressing adolescent substance use. Importantly, both provide evidence that upstream factors at the community and policy levels of the socio-ecological model are significantly associated with and have potential to address adolescent substance use. While the majority of literature on adolescent substance use is focused on individual and interpersonal level factors, this thesis work used social epidemiologic methods to study the contextual factors that shape downstream individual and interpersonal factors and may thus have more far-reaching impacts on adolescent health, and healthy equity. In times of austerity, exacerbated by the social and economic consequences of COVID-19, understanding the contextual factors that are associated with adolescent substance use is critical to protecting and improving adolescent health during a developmentally significant time in their lives. Research on the ways that PHUs can support adolescent health directly in schools, or the ways in which broader spending decisions relate to adolescent health, can offer evidence to inform future public health practice and resource allocation in a way that effectively protects and promotes adolescent growth and wellbeing.

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APPENDICES

Appendix A: Literature review on public health unit engagement in schools

In the context of collaboration with schools, the literature discusses a role for PHUs in surveillance and data collection, capacity building, program or service delivery, joint problem solving, and advocacy for policy change. Schools can benefit from understanding the incidence and prevalence of health outcomes among their student populations as this information can guide decisions on resource allocation, policy development, and public health interventions. Surveillance data are thus useful to help with planning and targeting of resources and interventions where they are needed most.[58] PHU support is especially useful given that public health surveillance activities and data interpretation are beyond the scope of responsibility for teaching staff. In Chicago, Illinois' DuPage County, the local PHU collaborated with schools to develop a system of childhood obesity surveillance whereby voluntarily submitted, secondary health data were interpreted and summarized to inform wellness policies for improved health outcomes.[78] These health data, specifically BMI and blood pressure readings, were collected as part of regular, state-mandated health examination forms. For schools, collaboration with a local PHU allowed them to use the data to support context-informed policy and resource allocation. Meanwhile, for DuPage County health department, collaboration with schools likely saved the PHU time and resources in the development of a local childhood obesity surveillance system. Similarly, during the COVID-19 pandemic, McHenry County health department in Chicago and Cincinnati health department have worked with schools to monitor and control COVID-19.[151,210] They tracked incident positive cases of COVID-19 and contacts of those who tested positive. Protocols for testing and reporting positive cases were also developed collaboratively.

Apart from surveillance and disease monitoring, data to inform school health policy and practice can be obtained from school-based research on intervention programs.[52,58,59,211] In Wood County West Virginia, a partnership between the local PHU, a university research center and a local school system allowed for school-based research on the association between physical activity and academic performance using secondary data provided by the school.[52] Study findings indicated that physical fitness was associated with higher academic performance. This suggested that investment in improved student physical activity may also improve students' academic success. New programs were subsequently introduced to improve student fitness, and

as more data became available, further research was undertaken to study the mechanisms of the observed association. School-based research informed intervention planning by the local PHU, while also evaluating those interventions to better understand their impact.

Capacity building is another way in which PHUs can support schools in promoting the health of children and youth. PHUs can increase capacity by offering material resources, human resources, and knowledge or expertise. For example, Lake County Health Department in Illinois partnered with the local school district to implement wellness programs in elementary schools.[75] Their goal was to promote health by identifying community-level social factors underlying health inequities. A School Wellness Partnership was formed, whereby the local health department's health equity team worked with school staff to identify which aspects of school health and wellbeing needed intervention, and created and implemented an action plan accordingly. For example, because childhood obesity was identified as a priority concern, an evidence-based, 5-week nutrition and physical activity program was implemented, involving numerous community members including a physician, public library staff, and parks and recreation staff. The local health department provided financial support for program implementation, as well as materials like promotional posters and activity kits for students to take home. Health department staff also provided their expertise in needs assessments, program development, program evaluation, and importantly, health equity.

Similar partnerships exist in other US states. In North Carolina, a partnership between local health departments and schools was formed to address childhood obesity through funding and training for policy and environmental change.[76] In Florida's Duval County, a partnership between the local PHU and schools allowed for greater capacity, in the form of expertise and resources, to address sexual and reproductive health, especially among at-risk youth.[53] In West Virginia's Wood County, the health department provided schools with staffing resources as well as their expertise in community planning and program implementation for improved student physical activity.[52] In all three cases, expertise and resources from health departments were key to health promotion and protection in schools. Importantly, these interventions were informed by the literature, or findings from school-based research such as needs assessments and stakeholder interviews.[52,53,75]

School specialists in California, who are employees of local PHUs as well as staff redirected from state-level departments, are another example of PHUs offering staffing resources

and expertise to build capacity for improved school health.[91] During the COVID-19 pandemic, school specialists received training to support COVID-19 related data management, outbreak response efforts in accordance with federal and state policies, as well as communication and information dissemination, all in the context of a school setting. This partnership aimed not only to keep students healthy, but to mitigate the negative impact of the COVID-19 pandemic on students' educational outcomes.

In addition to school specialists in California, two other examples of PHU engagement in the context of COVID-19 response are two local PHUs in Chicago and Cincinnati.[91,151,210] In Chicago's McHenry County, the county PHU worked with school nurses to establish a School Nurse Task Force and develop a toolkit for safe school operation during the COVID-19 pandemic.[151] Using their public health expertise, PHU staff provided up to date information to schools regarding COVID-19 and transmission control strategies, relying on pre-existing relationships between school nurses and public health nurses to convey this information. PHU staff met regularly with school nurses and other collaborators to discuss weekly case counts and disease control measures in schools. This included provision of training in contact tracing and provision of N95 masks and mask fit testing. Similar to McHenry County, the Cincinnati PHU worked with the local public school district and a local children's hospital to design and execute strategies to minimize the transmission of COVID-19 in a school setting.[210] Strategies included rapid testing, isolation and reporting of positive cases, contact tracing by school nurses and PHU epidemiologists, and regular meetings to reflect on and improve upon these infection control efforts.

Appendix B: Investigation of the pattern of public health unit engagement in schools over a three-year period

Does the consistency of public health engagement, as a variable fixed at baseline, impact the trend in adolescent substance use?

For this analysis, PHU engagement was defined by the pattern of engagement over time and modeled as a variable fixed at baseline. PHU engagement was categorized as being sustained, intermittent, or absent. Regarding alcohol and marijuana use prevention, 7 of 64 schools (11%) did not have their local PHU engaged at any time during the study period, from 2016/17 through 2018/19 whereas 21 schools (33%) had their local PHU consistently engaged during all three years. 36 schools (56%) had their local PHU engaged intermittently (1-2 years) over the study period. Regarding cigarette and e-cigarette use prevention, 5 of 58 schools (9%) did not have their local PHU engaged at any time during the study period. 25 schools (43%) had their local PHU consistently engaged all three years. 28 schools (48%) had their local PHU engaged intermittently (1-2 years) over the study period. There were 6 schools in 2017/18 that were missing data on public health engagement for tobacco/e-cigarette use.

To account for student grade but avoid its correlation with year, models investigating the fourth research question included an interaction between PHU engagement and grade, rather than PHU engagement and year. The sample was limited to students who were followed up for both years following baseline to ensure that exposure data were available all three years. When studying exposure to PHU engagement in addressing alcohol or marijuana use, the sample size was 8,600 students in 64 schools. When studying exposure to PHU engagement in addressing cigarette or e-cigarette use, the sample size was 7,609 students in 58 schools.

Results

Alcohol use

There were no significant differences in the odds of alcohol use by pattern of PHU engagement (Table B.1). Interactions between grade and pattern of PHU engagement were also non-significant, suggesting no difference, by PHU pattern of engagement, in the odds of alcohol use as students move into higher grades. The statistically non-significant odds of alcohol use among grade 12 students after adjusting for other factors and conditional on the random effect is 0.98 (95% CI: 0.51, 1.85) for those exposed to intermittent PHU engagement and 1.27 (95% CI:

0.64, 2.48) for those exposed to sustained PHU engagement compared to those exposed to no PHU engagement (Table B.6).

Alcohol binge drinking

Similar results were found for binge drinking. There were no significant differences in the odds of binge drinking by pattern of PHU engagement (Table B.2). Interactions between grade and pattern of PHU engagement were non-significant, suggesting no difference, by PHU pattern of engagement, in the odds of binge drinking as students move into higher grades. The statistically non-significant odds of binge drinking among grade 12 students after adjusting for other factors and conditional on the random effect is 1.03 (95% CI: 0.51, 2.07) for those exposed to intermittent PHU engagement and 1.13 (95% CI: 0.54, 2.39) for those exposed to sustained PHU engagement compared to those exposed to no PHU engagement (Table B.6).

Cannabis use

There were no significant differences in the odds of cannabis use by pattern of PHU engagement (Table B.3), nor were there any significant interactions with grade. The statistically non-significant odds of cannabis use among grade 12 students after adjusting for other factors and conditional on the random effect is 1.52 (95% CI: 0.79, 2.91) for those exposed to intermittent PHU engagement and 1.36 (95% CI: 0.69, 2.69) for those exposed to sustained PHU engagement compared to those exposed to no PHU engagement (Table B.6).

Cigarette use

There were no significant differences in the odds of cigarette use by pattern of PHU engagement (Table B.4), nor were there any significant interactions with grade. The statistically non-significant odds of cigarette use among grade 12 students after adjusting for other factors and conditional on the random effect is 0.54 (95% CI: 0.20, 1.46) for those exposed to intermittent PHU engagement and 0.57 (95% CI: 0.21, 1.56) for those exposed to sustained PHU engagement compared to those exposed to no PHU engagement (Table B.6).

E-cigarette use

As with the other outcomes studied here, there were no significant differences in the odds of e-cigarette use by pattern of PHU engagement (Table B.5), nor were there any significant interactions with grade. The statistically non-significant odds of e-cigarette use among grade 12 students after adjusting for other factors and conditional on the random effect is 0.74 (95% CI: 0.36, 1.52) for those exposed to intermittent PHU engagement and 0.94 (95% CI: 0.46, 1.92) for those exposed to sustained PHU engagement compared to those exposed to no PHU engagement (Table B.6).

Table B.1. Association between the longitudinal pattern of public health engagement and adolescent monthly alcohol use, over a three-year period from 2016/17 to 2018/19.

	Past-month alcohol use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.23 (0.01, 0.04)**	**0.04 (0.02, 0.08)**	**0.06 (0.02, 0.16)**
Engagement (ref: None)			
Intermittent	1.35 (0.58, 3.13)	1.28 (0.60, 2.70)	1.37 (0.65, 2.87)
Sustained	1.36 (0.57, 3.25)	1.32 (0.61, 2.86)	1.68 (0.77, 3.63)
Grade (ref: 9)			
10	**5.79 (3.54, 9.48)**	**5.49 (3.36, 8.95)**	**5.47 (3.35, 8.92)**
11	**15.38 (9.39, 25.20)**	**14.52 (8.90, 23.69)**	**14.48 (8.87, 23.64)**
12	**28.19 (16.21, 49.02)**	**25.89 (14.95, 44.84)**	**25.77 (14.87, 44.64)**
Engagement*grade			
Intermittent*10	0.96 (0.57, 1.64)	0.96 (0.56, 1.62)	0.96 (0.57, 1.63)
Intermittent*11	0.85 (0.50, 1.44)	0.85 (0.50, 1.450	0.86 (0.51, 1.45)
Intermittent*12	0.74 (0.41, 1.34)	0.71 (0.39, 1.29)	0.71 (0.39, 1.29)
Sustained*10	0.64 (0.38, 1.10)	0.65 (0.38, 1.11)	0.65 (0.38, 1.11)
Sustained*11	0.65 (0.38, 1.12)	0.67 (0.39, 1.14)	0.67 (0.39, 1.14)
Sustained*12	0.76 (0.41, 1.39)	0.74 (0.41, 1.36)	0.75 (0.41, 1.37)
Sex (ref: Female)			
Male		**1.17 (1.02, 1.35)**	**1.17 (1.02, 1.34)**
Race (ref: White)			
Black		**0.36 (0.24, 0.56)**	**0.37 (0.24, 0.57)**
Asian		**0.19 (0.14, 0.26)**	**0.19 (0.14, 0.27)**
Latinx		0.67 (0.42, 1.05)	0.67 (0.42, 1.06)
Other		**0.65 (0.48, 0.86)**	**0.64 (0.48, 0.85)**
Multi		0.84 (0.65, 1.08)	0.84 (0.66, 1.08)

Table B.1. Continued.

	Past-month alcohol use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Spending Money (ref: $0)			
$1-$20		**2.56 (2.10, 3.12)**	**2.56 (2.10, 3.12)**
$21-$100		**5.28 (4.24, 6.58)**	**5.27 (4.23, 6.56)**
$100+		**9.63 (7.19, 12.89)**	**9.57 (7.14, 12.82)**
Do not know		**2.27 (1.78, 2.91)**	**2.27 (1.78, 2.90)**
Connectedness		**0.93 (0.91, 0.95)**	**0.93 (0.91, 0.95)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.69 (0.40, 1.19)
3rd quartile			0.76 (0.44, 1.32)
4th quartile			**0.50 (0.26, 0.97)**
Rural (ref: Urban)			
Rural			0.79 (0.47, 1.34)
School Size (ref: Small)			
Medium			**0.61 (0.39, 0.94)**
Large			**0.54 (0.30, 0.95)**
Province (ref: Ontario)			
Alberta			1.81 (0.83, 3.94)
British Columbia			0.81 (0.35, 1.87)

[1] Engagement level "None" means there was no involvement by public health throughout the three years. "Intermittent" means public health engagement occurred for 1 or 2 of the three years. "Sustained" engagement refers to public health engagement all three years of the study period.
Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table B.2. Association between the longitudinal pattern of public health engagement and adolescent monthly alcohol binge drinking, over a three-year period from 2016/17 to 2018/19.

	Past-month binge drinking		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.004 (0.001, 0.010)**	**0.008 (0.003, 0.024)**	**0.02 (0.01, 0.05)**
Engagement (ref: None)			
Intermittent	1.45 (0.52, 4.08)	1.39 (0.53, 3.67)	1.48 (0.57, 3.84)
Sustained	1.34 (0.46, 3.89)	1.30 (0.48, 3.53)	1.78 (0.67, 4.76)
Grade (ref: 9)			
10	**6.65 (3.24, 13.61)**	**6.33 (3.10, 12.94)**	**6.30 (3.08, 12.88)**
11	**16.76 (8.24, 34.09)**	**15.75 (7.77, 31.94)**	**15.69 (7.73, 31.84)**
12	**40.00 (18.65, 85.77)**	**35.75 (16.75, 76.31)**	**35.40 (16.57, 75.60)**
Engagement*grade			
Intermittent*10	1.05 (0.49, 2.27)	1.02 (0.47, 2.20)	1.03 (0.48, 2.21)
Intermittent*11	1.04 (0.49, 2.23)	1.04 (0.49, 2.20)	1.04 (0.49, 2.21)
Intermittent*12	0.72 (0.32, 1.62)	0.69 (0.31, 1.55)	0.69 (0.31, 1.56)
Sustained*10	0.65 (0.30, 1.41)	0.64 (0.29, 1.39)	0.64 (0.30, 1.40)
Sustained*11	0.73 (0.34, 1.58)	0.74 (0.35, 1.59)	0.74 (0.35, 1.60)
Sustained*12	0.65 (0.28, 1.48)	0.63 (0.28, 1.43)	0.64 (0.28, 1.45)
Sex (ref: Female)			
Male		**1.26 (1.08, 1.48)**	**1.26 (1.08, 1.47)**
Race (ref: White)			
Black		0.68 (0.42, 1.11)	0.70 (0.43, 1.14)
Asian		**0.26 (0.18, 0.39)**	**0.27 (0.19, 0.40)**
Latinx		0.84 (0.50, 1.41)	0.84 (0.50, 1.41)
Other		0.87 (0.63, 1.20)	0.86 (0.62, 1.19)
Multi		0.86 (0.65, 1.13)	0.86 (0.65, 1.14)

Table B.2. Continued

	Past-month binge drinking		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Spending Money (ref: $0)			
$1-$20		**2.45 (1.93, 3.09)**	**2.45 (1.94, 3.10)**
$21-$100		**4.84 (3.76, 6.22)**	**4.83 (3.75, 6.21)**
$100+		**9.47 (6.90, 13.00)**	**9.40 (6.85, 12.91)**
Do not know		**2.70 (2.03, 3.58)**	**2.69 (2.03, 3.57)**
Connectedness		**0.91 (0.89, 0.94)**	**0.91 (0.89, 0.94)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.65 (0.36, 1.17)
3rd quartile			0.65 (0.35, 1.18)
4th quartile			**0.32 (0.15, 0.67)**
Rural (ref: Urban)			
Rural			0.82 (0.46, 1.45)
School Size (ref: Small)			
Medium			0.63 (0.39, 1.03)
Large			0.62 (0.33, 1.15)
Province (ref: Ontario)			
Alberta			**3.23 (1.35, 7.69)**
British Columbia			0.76 (0.30, 1.94)

[1] Engagement level "None" means there was no involvement by public health throughout the three years. "Intermittent" means public health engagement occurred for 1 or 2 of the three years. "Sustained" engagement refers to public health engagement all three years of the study period.

Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table B.3. Association between the longitudinal pattern of public health engagement and adolescent monthly cannabis use, over a three-year period from 2016/17 to 2018/19.

	Past-month cannabis use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.0006 (0.0002,0.0017)**	**0.04 (0.01, 0.11)**	**0.05 (0.02, 0.17)**
Engagement (ref: None)			
Intermittent	1.36 (0.48, 3.90)	1.09 (0.41, 2.92)	1.04 (0.39, 2.77)
Sustained	0.89 (0.30, 2.64)	0.81 (0.29, 2.25)	0.81 (0.30, 2.24)
Grade (ref: 9)			
10	**6.44 (2.76, 15.00)**	**5.40 (2.40, 12.13)**	**5.44 (2.42, 12.23)**
11	**26.32 (11.39, 60.82)**	**20.97 (9.45, 46.55)**	**21.15 (9.53, 46.95)**
12	**59.99 (23.94, 150.33)**	**42.95 (17.88, 103.19)**	**43.80 (18.21, 105.30)**
Engagement*grade			
Intermittent*10	1.46 (0.58, 3.63)	1.53 (0.63, 3.67)	1.51 (0.63, 3.64)
Intermittent*11	0.97 (0.40, 2.37)	1.05 (0.45, 2.47)	1.04 (0.44, 2.45)
Intermittent*12	1.37 (0.52, 3.63)	1.49 (0.58, 3.79)	1.46 (0.57, 3.72)
Sustained*10	1.44 (0.56, 3.69)	1.49 (0.60, 3.67)	1.48 (0.60, 3.65)
Sustained*11	1.70 (0.68, 4.26)	1.76 (0.73, 4.25)	1.75 (0.72, 4.22)
Sustained*12	1.63 (0.60, 4.46)	1.70 (0.65, 4.46)	1.67 (0.64, 4.39)
Sex (ref: Female)			
Male		**1.90 (1.56, 2.31)**	**1.90 (1.56, 2.30)**
Race (ref: White)			
Black		1.09 (0.62, 1.91)	1.12 (0.64, 1.97)
Asian		**0.26 (0.16, 0.42)**	**0.26 (0.16, 0.43)**
Latinx		0.87 (0.45, 1.66)	0.85 (0.44, 1.62)
Other		**2.27 (1.56, 3.29)**	**2.30 (1.58, 3.34)**
Multi		1.24 (0.88, 1.74)	1.26 (0.89, 1.77)

Table B.3. Continued.

	Past-month cannabis use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Spending Money (ref: $0)			
$1-$20		**2.05 (1.55, 2.73)**	**2.07 (1.56, 2.74)**
$21-$100		**3.47 (2.56, 4.70)**	**3.48 (2.57, 4.72)**
$100+		**5.59 (3.81, 8.22)**	**5.54 (3.77, 8.15)**
Do not know		1.35 (0.94, 1.93)	1.35 (0.94, 1.93)
Connectedness		**0.78 (0.75, 0.81)**	**0.78 (0.75, 0.81)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			1.25 (0.74, 2.10)
3rd quartile			0.99 (0.58, 1.67)
4th quartile			0.55 (0.29, 1.05)
Rural (ref: Urban)			
Rural			**0.42 (0.25, 0.71)**
School Size (ref: Small)			
Medium			0.79 (0.51, 1.23)
Large			0.84 (0.49, 1.43)
Province (ref: Ontario)			
Alberta			1.48 (0.67, 3.25)
British Columbia			1.09 (0.50, 2.36)

[1] Engagement level "None" means there was no involvement by public health throughout the three years. "Intermittent" means public health engagement occurred for 1 or 2 of the three years. "Sustained" engagement refers to public health engagement all three years of the study period.

Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table B.4. Association between the longitudinal pattern of public health engagement and adolescent monthly **cigarette** use, over a three-year period from 2016/17 to 2018/19.

	Past-month cigarette use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.0011 (0.0002, 0.0052)**	**0.05 (0.01, 0.23)**	**0.18 (0.04, 0.82)**
Engagement (ref: None)			
Intermittent	1.77 (0.35, 8.89)	1.28 (0.30, 5.48)	0.86 (0.22, 3.28)
Sustained	1.46 (0.29, 7.35)	1.17 (0.27, 5.02)	1.12 (0.29, 4.29)
Grade (ref: 9)			
10	**2.99 (1.01, 8.88)**	2.71 (0.93, 7.93)	2.68 (0.91, 7.87)
11	**12.54 (4.43, 35.48)**	**11.10 (3.99, 30.92)**	**11.04 (3.95, 30.82)**
12	**15.10 (4.83, 47.18)**	**12.33 (4.03, 37.69)**	**12.07 (3.94, 36.98)**
Engagement*grade			
Intermittent*10	1.12 (0.35, 3.60)	1.16 (0.37, 3.70)	1.16 (0.37, 3.71)
Intermittent*11	0.44 (0.14, 1.35)	0.47 (0.16, 1.42)	0.47 (0.16, 1.42)
Intermittent*12	0.58 (0.17, 2.00)	0.63 (0.19, 2.11)	0.63 (0.19, 2.12)
Sustained*10	1.02 (0.32, 3.25)	1.07 (0.34, 3.38)	1.09 (0.34, 3.44)
Sustained*11	0.45 (0.15, 1.36)	0.48 (0.16, 1.44)	0.49 (0.16, 1.46)
Sustained*12	0.46 (0.14, 1.57)	0.49 (0.15, 1.65)	0.51 (0.15, 1.70)
Sex (ref: Female)			
Male		**1.72 (1.36, 2.17)**	**1.71 (1.36, 2.16)**
Race (ref: White)			
Black		1.17 (0.59, 2.33)	1.26 (0.64, 2.51)
Asian		**0.36 (0.20, 0.67)**	**0.39 (0.21, 0.71)**
Latinx		0.47 (0.19, 1.19)	0.46 (0.18, 1.17)
Other		**2.08 (1.37, 3.17)**	**2.12 (1.39, 3.22)**
Multi		1.38 (0.92, 2.07)	1.41 (0.94, 2.12)

Table B.4. Continued.

	Past-month cigarette use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Spending Money (ref: $0)			
$1-$20		**1.91 (1.34, 2.71)**	**1.91 (1.35, 2.72)**
$21-$100		**2.80 (1.93, 4.06)**	**2.78 (1.92, 4.03)**
$100+		**4.41 (2.84, 6.87)**	**4.34 (2.79, 6.75)**
Do not know		**1.81 (1.18, 2.79)**	**1.79 (1.16, 2.74)**
Connectedness		**0.79 (0.76, 0.82)**	**0.79 (0.76, 0.82)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.57 (0.27, 1.19)
3rd quartile			1.07 (0.51, 2.23)
4th quartile			**0.20 (0.08, 0.52)**
Rural (ref: Urban)			
Rural			1.18 (0.57, 2.45)
School Size (ref: Small)			
Medium			**0.39 (0.21, 0.72)**
Large			**0.24 (0.10, 0.54)**
Province (ref: Ontario)			
Alberta			**4.32 (1.43, 13.11)**
British Columbia			0.58 (0.19, 1.76)

[1] Engagement level "None" means there was no involvement by public health throughout the three years. "Intermittent" means public health engagement occurred for 1 or 2 of the three years. "Sustained" engagement refers to public health engagement all three years of the study period.
Note: **Bold** indicates statistical significance at $p \leq 0.05$

Table B.5. Association between the longitudinal pattern of public health engagement and adolescent monthly e-cigarette use, over a three-year period from 2016/17 to 2018/19.

	Past-month e-cigarette use		
Variable	**Model 1 (95% CI)**	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Constant	**0.004 (0.002, 0.011)**	**0.007 (0.003, 0.021)**	**0.008 (0.002, 0.024)**
Engagement (ref: None)			
Intermittent	1.57 (0.58, 4.25)	1.35 (0.52, 3.50)	1.38 (0.53, 3.55)
Sustained	0.77 (0.28, 2.09)	0.69 (0.27, 1.79)	0.84 (0.33, 2.17)
Grade (ref: 9)			
10	**7.69 (3.73, 15.88)**	**7.41 (3.59, 15.29)**	**7.36 (3.56, 15.18)**
11	**43.86 (21.32, 90.22)**	**41.50 (20.20, 85.26)**	**41.20 (20.06, 84.62)**
12	**101.22 (46.21, 221.71)**	**89.76 (41.13, 195.90)**	**88.38 (40.50, 192.87)**
Engagement*grade			
Intermittent*10	0.50 (0.23, 1.08)	0.49 (0.22, 1.07)	0.49 (0.23, 1.07)
Intermittent*11	0.54 (0.25, 1.15)	0.54 (0.25, 1.15)	0.54 (0.25, 1.16)
Intermittent*12	0.54 (0.23, 1.23)	0.53 (0.23, 1.22)	0.54 (0.24, 1.24)
Sustained*10	0.92 (0.43, 2.01)	0.92 (0.42, 2.00)	0.93 (0.43, 2.01)
Sustained*11	0.81 (0.38, 1.74)	0.82 (0.38, 1.76)	0.83 (0.39, 1.77)
Sustained*12	1.08 (0.47, 2.48)	1.09 (0.48, 2.49)	1.11 (0.49, 2.53)
Sex (ref: Female)			
Male		**2.14 (1.82, 2.53)**	**2.13 (1.81, 2.52)**
Race (ref: White)			
Black		**0.60 (0.36, 0.98)**	0.62 (0.38, 1.01)
Asian		**0.22 (0.15, 0.32)**	**0.22 (0.15, 0.32)**
Latinx		0.94 (0.56, 1.57)	0.94 (0.56, 1.57)
Other		1.01 (0.73, 1.41)	1.01 (0.73, 1.41)
Multi		1.03 (0.77, 1.39)	1.04 (0.77, 1.40)

Table B.5. Continued.

	Past-month e-cigarette use		
	Model 1 (95% CI)	**Model 2 (95% CI)**	**Model 3 (95% CI)**
Spending Money (ref: $0)			
$1-$20		**2.70 (2.13, 3.44)**	**2.72 (2.14, 3.45)**
$21-$100		**4.05 (3.12, 5.25)**	**4.06 (3.13, 5.26)**
$100+		**6.46 (4.61, 9.06)**	**6.45 (4.60, 9.03)**
Do not know		**2.28 (1.70, 3.06)**	**2.29 (1.71, 3.06)**
Connectedness		**0.92 (0.89, 0.95)**	**0.92 (0.90, 0.95)**
Median after tax household income (ref: 1st quartile)			
2nd quartile			0.95 (0.55, 1.63)
3rd quartile			0.99 (0.57, 1.72)
4th quartile			**0.47 (0.24, 0.91)**
Rural (ref: Urban)			
Rural			0.68 (0.39, 1.20)
School Size (ref: Small)			
Medium			1.00 (0.63, 1.58)
Large			0.74 (0.40, 1.36)
Province (ref: Ontario)			
Alberta			**2.90 (1.30, 6.45)**
British Columbia			1.94 (0.89, 4.26)

[1] Engagement level "None" means there was no involvement by public health throughout the three years. "Intermittent" means public health engagement occurred for 1 or 2 of the three years. "Sustained" engagement refers to public health engagement all three years of the study period.

Note: **Bold** indicates statistical significance at $p \leq 0.05$

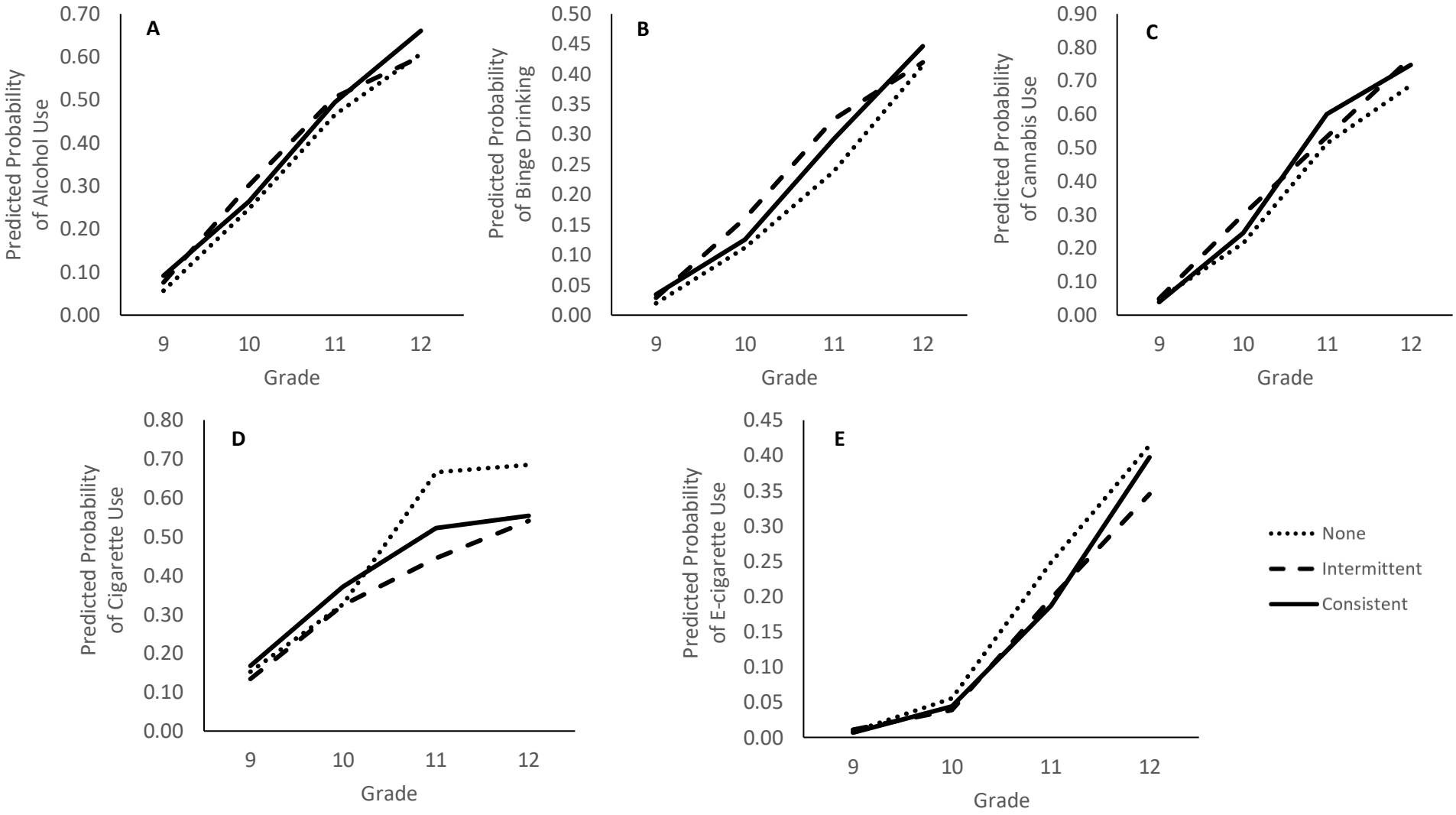

Figure B.1. Probability of adolescent alcohol use, binge drinking, cannabis use, cigarette use, and e-cigarette use (A-E respectively) as predicted by the pattern of public health unit engagement in COMPASS secondary schools from 2016/2017 to 2018/2019.

Table B.6. Adjusted odds of alcohol, cannabis, cigarette and e-cigarette use in 2018/19 for students exposed to intermittent or sustained public health engagement from 2016/17 through 2018/19.

Engagement	OR	95% CI
Reference: No engagement, grade 9		
Alcohol Use		
Intermittent	0.98	(0.51, 1.85)
Sustained	1.26	(0.64, 2.48)
Binge Drinking		
Intermittent	1.03	(0.51, 2.07)
Sustained	1.13	(0.54, 2.39)
Cannabis Use		
Intermittent	1.52	(0.79, 2.91)
Sustained	1.36	(0.69, 2.69)
Cigarette Use		
Intermittent	0.54	(0.20, 1.46)
Sustained	0.57	(0.21, 1.56)
E-cigarette Use		
Intermittent	0.74	(0.36, 1.52)
Sustained	0.94	(0.46, 1.92)

Appendix C: Comparing students remaining with students lost to follow up in a longitudinal study of PHU engagement

Table C.1 Characteristics of students lost to follow up compared with those remaining in final sample by 2018/19.

	Sample lost to follow up (N=8,153)		**Remaining sample** (N=8,422)		**Chi Square / T-test**		
Variable	**N**	**%**	**N**	**%**	**df**	**Statistic**	**p-value**
Sex					1	0.01	0.94
Female	4,234	51.93	4,379	51.99			
Male	3,919	48.07	4,043	48.01			
Grade					3	$4.5x10^3$	<0.001
9	1,948	23.89	4,482	53.22			
10	2,326	28.53	3,705	43.99			
11	3,626	44.47	223	2.65			
12	253	3.10	12	0.14			
Race					4	11.15	0.03
White	5,828	71.48	5,995	71.18			
Black	287	3.52	263	3.12			
Asian	557	6.83	677	8.04			
Latinx	196	2.40	209	2.48			
Other	1,285	15.76	1,278	15.17			
Weekly Spending Money					4	448.22	<0.001
Zero	1,396	17.12	1,787	21.22			
$1-$20	2,226	27.30	2,959	35.13			
$21-$100	2,128	26.10	1,826	21.68			
$100+	1,400	17.17	664	7.88			
Don’t know	1,003	12.30	1,186	14.08			

Binge drinking	6,740	82.67	7,696	91.38	1	279.67	<0.001
No	1,413	17.33	726	8.62			
Yes							
Alcohol use					1	332.51	<0.001
No	5,616	68.88	6,833	81.13			
Yes	2,537	31.12	1,589	18.87			
Cannabis use					1	211.56	<0.001
No	7,130	87.45	7,916	93.99			
Yes	1,023	12.55	506	6.01			
Cigarette use					1	132.22	<0.001
No	7,501	92.00	8,102	96.20			
Yes	652	8.00	320	3.80			
E-cigarette use					1	68.35	<0.001
No	7,248	88.90	7,800	92.61			
Yes	905	11.10	622	7.39			
School connectedness	**Mean**	**SD**	**Mean**	**SD**	**df**	**Statistic**	**p-value**
	18.24	0.04	18.73	0.03	16573	-10.31	<0.001

Appendix D: Comparing characteristics of schools with and without exposure to public health unit engagement

Table D.1 Characteristics of schools exposed or unexposed to PHU engagement in addressing alcohol/marijuana use (N=68).

	Exposure to baseline PHU engagement (N=44)		**No exposure** to baseline PHU engagement (N=24)		**Chi Square / T-test**		
Variable	**N**	**%**	**N**	**%**	**df**	**Statistic**	**p-value**
Province					2	0.65	0.72
Ontario	38	86	19	79			
Alberta	4	9	3	13			
British Columbia	2	5	2	8			
Missing							
Median Income					66	-1.19	0.24
First quartile	6	14	9	38			
Second quartile	16	36	3	13			
Third quartile	11	25	8	33			
Fourth quartile	11	25	4	17			
Missing							
Rurality					1	3.13	0.08
Urban	40	91	18	75			
Rural	4	9	6	25			
Missing							
Enrolment size					2	3.15	0.21
Small	10	23	10	42			
Medium	26	59	12	50			
Large	8	18	2	8			
Missing							

Table D.2 Characteristics of schools exposed or unexposed to PHU engagement in addressing cigarette/e-cigarette use (N=68).

	Exposure to baseline PHU engagement (N=44)		**No exposure** to baseline PHU engagement (N=24)		**Chi Square / T-test**		
Variable	**N**	**%**	**N**	**%**	**df**	**Statistic**	**p-value**
Province					2	0.65	0.72
Ontario	38	86	19	79			
Alberta	4	9	3	13			
British Columbia	2	5	2	8			
Missing							
Median Income					66	0.00	1.00
First quintile	9	20	6	25			
Second quintile	14	32	5	21			
Third quintile	11	25	8	33			
Fourth quintile	10	23	5	21			
Missing							
Rurality					1	0.11	0.74
Urban	38	86	20	83			
Rural	6	14	4	17			
Missing							
Enrolment size					2	1.87	0.39
Small	11	25	9	38			
Medium	25	57	13	54			
Large	8	18	2	8			
Missing							

Appendix E: Comparing students with complete data at baseline and those excluded due to missing data in PHU engagement study

Table E.1 Characteristics of students with complete data at baseline (2016/17) (n=16,575) compared to those excluded due to missing data at baseline (n=935).

	Cohort with complete data at baseline (n=16,575)		**Excluded (missingness at baseline)** (n=935)		**Chi Square / T-test**		
Variable	**N**	**%**	**N**	**%**	**df**	**Statistic**	**p-value**
Gender					1	21.58	<0.001
Female	8,613	51.96	348	43.55			
Male	7,962	48.04	451	56.45			
Missing	0		136				
Grade					3	2.13	0.55
9	6,430	38.79	324	36.61			
10	6,031	36.39	329	37.18			
11	3,849	23.22	215	24.29			
12	265	1.60	17	1.92			
Missing	0		50				
Race					5	24.35	<0.001
White	11,823	71.33	554	65.18			
Black	550	3.32	49	5.76			
Asian	1,234	7.44	64	7.53			
Latinx	405	2.44	25	2.94			
Other	2,563	7.02	158	8.24			
Missing	0	8.45	85	10.35			
Weekly spending money							
Zero	3,183	19.20	172	20.95	4	6.81	0.15
$1-$20	5,185	31.28	237	28.87			
$21-$100	3,954	23.86	178	21.68			

$100+	2,064	12.45	116	14.13			
Don't know	2,189	13.21	118	14.37			
Missing	0		114				
Binge drinking					1	0.05	0.82
No	14,436	87.10	774	87.36			
Yes	2,139	12.90	112	12.64			
Missing	0		49				
Alcohol use					1	18.91	<0.001
No	12,449	75.11	437	67.54			
Yes	4,126	24.89	210	32.46			
Missing	0		288				
Cannabis use					1	21.43	<0.001
No	15,046	90.78	554	85.36			
Yes	1,529	9.22	95	14.64			
Missing	0		286				
Cigarette use					1	13.08	<0.001
No	15,603	94.14	706	90.98			
Yes	972	5.86	70	9.02			
Missing	0		159				
E-cigarette use					1	18.34	<0.001
No	15,048	90.79	481	85.44			
Yes	1,527	9.21	82	14.56			
Missing	0		372				
	Mean	**SD**	**Mean**	**SD**	**df**	**Statistic**	**p-value**
School Connectedness Mean, SD	18.49	0.02	17.96	0.14	17141	4.02	<0.001
	0		367				

Appendix F: Equations for multilevel model of PHU engagement and past-month alcohol use

Outcome: alcohol_use
Level-1 variables: year
Level-2 variables: sex, race, grade, weekly spending money, connectedness
Level-3 variables: PHU engagement, median income, rurality, school size, province
Interaction term: PHU engagement*year

Level-1 equation

$alcohol\_use_{ijk} = \pi_{0jk} + \pi_{1jk}year_{ijk} + \varepsilon_{ijk}$

Level-2 equation

$\pi_{0jk} = \gamma_{00k} + \gamma_{01k}Sex_{jk} + \gamma_{02k}Race_{jk} + \gamma_{03k}Grade_{jk} + \gamma_{04k}SpendMoney_{jk} + \gamma_{05k}Connectedness_{jk} + u_{0jk}$

$\pi_{1jk} = \gamma_{10k}$

Level-3 equation

$\gamma_{00k} = \delta_{000} + \delta_{001}PHUengage_k + \delta_{002}MedianIncome_k + \delta_{003}Rurality_k + \delta_{004}SchoolSize_k + \delta_{005}Province_k + \upsilon_{00k}$

$\gamma_{01k} = \delta_{010}$

$\gamma_{02k} = \delta_{020}$

$\gamma_{03k} = \delta_{030}$

$\gamma_{04k} = \delta_{040}$

$\gamma_{05k} = \delta_{050}$

$\gamma_{10k} = \delta_{100} + \delta_{110}PHUengage_k$

$i=1, 2,..,m_{jk}$
$j=1, 2,...,n_k$
$k=1,2,...,68$

Composite Model/Equation

$alcohol\_use_{ijk} = \delta_{000} + \delta_{100}Years_{ijk} + \delta_{110}PHUengage_k*Years_{ijk} + \delta_{010}Sex_{jk} + \delta_{020}Race_{jk} + \delta_{030}Grade_{jk} + \delta_{040}SpendMoney_{jk} + \delta_{050}Connectedness_{jk} + \delta_{001}PHUengage_k + \delta_{002}MedianIncome_k + \delta_{003}Rurality_k + \delta_{004}SchoolSize_k + \delta_{005}Province_k + u_{0jk} + \upsilon_{00k} + \varepsilon_{ijk}$

ε_{ijk} is assumed to be independent of u_{0jk}, and υ_{00k}; and
u_{0jk} is independent of υ_{00k}; and
$\varepsilon_{ijk} \sim N(0,\sigma_e^2)$, $u_{0jk} \sim N(0,\sigma_{u0}^2)$, and $\upsilon_{00k} \sim N(0,\sigma\upsilon_0^2)$

Appendix G : Calculation for predicted probability

Figure G.1 Overall predicted probability and plausible value range

Overall predicted probability:		$1 / 1 + e^{-\gamma 00}$
	Where	e = exponential $\gamma 00$ = Coefficient of the intercept
Plausible value range:		Lower bound: $1 / 1 + e^{-[\gamma 00 - 1.96\sqrt{\tau 00}]}$ Upper bound: $1 / 1 + e^{-[\gamma 00 + 1.96\sqrt{\tau 00}]}$
	Where	e = exponential $\gamma 00$ = Coefficient of the intercept $\tau 00$ = residual area-level variation

Figure adapted from Raudenbush & Bryk[212], by R. Pabayo, PhD, written document, 2015.

Appendix H: Equations for multilevel model of PHU spending and past-month e-cigarette use

Outcome: e-cigarette_use
Level-1 variables: sex, race, grade, weekly spending money
Level-2 variables: rurality, school size
Level-3 variables: per capita spending quartile, instability score, deprivation score, ethnic concentration score

Level-1 equation

$$\text{e-cigarette\_use}_{ijk} = \pi_{0jk} + \pi_{1jk}\text{Sex}_{ijk} + \pi_{2jk}\text{Race}_{ijk} + \pi_{3jk}\text{Grade}_{ijk} + \pi_{4jk}\text{SpendMoney}_{ijk} + \varepsilon_{ijk}$$

Level-2 equation

$$\pi_{0jk} = \gamma_{00k} + \gamma_{01k}\text{SchoolSize}_{jk} + \gamma_{02k}\text{Rurality}_{jk} + u_{0jk}$$
$$\pi_{1jk} = \gamma_{10k}$$
$$\pi_{2jk} = \gamma_{20k}$$
$$\pi_{3jk} = \gamma_{30k}$$
$$\pi_{4jk} = \gamma_{40k}$$

Level-3 equation

$$\gamma_{00k} = \delta_{000} + \delta_{001}\text{Spending}_{k} + \delta_{002}\text{Instability}_{k} + \delta_{003}\text{Deprivation}_{k} + \delta_{004}\text{EthnicCon}_{k} + \upsilon_{00k}$$
$$\gamma_{01k} = \delta_{010}$$
$$\gamma_{02k} = \delta_{020}$$
$$\gamma_{10k} = \delta_{100}$$
$$\gamma_{20k} = \delta_{200}$$
$$\gamma_{30k} = \delta_{300}$$
$$\gamma_{40k} = \delta_{400}$$

$i=1, 2,..,m_{jk}$
$j=1, 2,...,n_{k}$
$k=1,2,...,15$

Composite Model/Equation

$$\text{e-cigarette\_use}_{ijk} = \delta_{000} + \delta_{010}\text{Sex}_{ijk} + \delta_{020}\text{Race}_{ijk} + \delta_{030}\text{Grade}_{ijk} + \delta_{040}\text{SpendMoney}_{ijk} + \delta_{010}\text{SchoolSize}_{jk} + \delta_{020}\text{Rurality}_{jk} + \delta_{001}\text{Spending}_{k} + \delta_{002}\text{Instability}_{k} + \delta_{003}\text{Deprivation}_{k} + \delta_{004}\text{EthnicCon}_{k} + u_{0jk} + \upsilon_{00k} + \varepsilon_{ijk}$$

ε_{ijk} is assumed to be independent of u_{0jk}, and υ_{00k}; and
u_{0jk} is independent of υ_{00k}; and
$\varepsilon_{ijk} \sim N(0,\sigma_e^2)$, $u_{0jk} \sim N(0,\sigma_{u0}^2)$, and $\upsilon_{00k} \sim N(0,\sigma\upsilon_0^2)$

Appendix I: Comparing students with complete data and those excluded due to missing data in PHU spending study

Table I.1. Characteristics of study sample before and after excluding participants with missing data, including missing outcome information on past-month alcohol use.

	Sample with complete data at baseline (n=29,434)		**Original sample** (n=30,675)		**Excluded due to missing data** (n=1,241)				
Variable	**n**	**%**	**n**	**%**	**n**	**%**	**df**	**chi**	**p-value**
Gender							1	57.17	<0.001
Female	14,550	49	14,852	49	302	36			
Male	14,884	51	15,417	51	533	64			
Missing			406		406				
Grade							3	22.63	<0.001
9	8,313	28	8,618	28	305	35			
10	7,920	27	8,144	27	224	26			
11	7,120	24	7,290	24	170	20			
12	6,081	21	6,249	21	168	19			
Missing			374		374				
Race							4	151.48	<0.001
White	19,594	67	20,049	66	455	49			
Black	1,872	6	1,983	7	111	12			
Asian	2,569	9	2,677	9	108	12			
Latinx	1,415	5	1,457	5	42	5			
Other	3,984	14	4,197	14	213	23			
Missing			312		312				

Weekly Spending money									
Zero	5,268	18	5,449	18	181	21	4	16.57	0.002
$1-$20	7,126	24	7,327	24	201	24			
$21-$100	6,828	23	6,983	23	155	18			
$100+	6,249	21	6,433	21	184	22			
Don't know	3,963	13	4,094	14	131	15			
Missing			389		389				
Variable	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**df**	**chi**	**p-value**
Residential Instability	-0.070 0.209	-0.029	-0.070 0.209	-0.029	-0.075 0.212	-0.069	30673	0.8115	0.417
Material Deprivation	-0.006 0.187	0.012	-0.006 0.186	0.012	-0.005 0.174	0.012	30673	-0.3466	0.729
Dependency	0.092 0.285	0.121	0.092 0.285	0.121	0.075 0.288	0.121	30673	2.1521	0.031
Ethnic Concentration	-0.350 0.345	-0.477	-0.350 .345	-0.477	-0.337 0.341	-0.477	30673	-1.3104	0.190

Table I.2. Characteristics of study sample before and after excluding participants with missing data, including missing outcome information on past-month binge drinking.

	Sample with complete data at baseline (n=29,788)		**Original sample** (n=30,675)		**Excluded due to missing data** (n=887)				
Variable	**n**	**%**	**n**	**%**	**n**	**%**	**df**	**chi**	**p-value**
Gender							1	16.37	<0.001
Female	14,660	49	14,852	49	192	40			
Male	15,128	51	15,417	51	289	60			
Missing			406		406				
Grade							3	35.94	<0.001
9	8,415	28	8,618	28	203	40			
10	8,019	27	8,144	27	125	24			
11	7,204	24	7,290	24	86	17			
12	6,150	21	6,249	21	99	19			
Missing			374		374				
Race							4	103.17	<0.001
White	19,764	66	20,049	66	285	50			
Black	1,925	6	1,983	7	58	10			
Asian	2,623	9	2,677	9	54	9			
Latinx	1,431	5	1,457	5	26	5			
Other	4,045	14	4,197	14	152	26			
Missing			312		312				

Weekly Spending money

Zero	5,345	18	5,449	18	104	21	4	26.58	<0.001
$1-$20	7,227	24	7,327	24	100	20			
$21-$100	6,903	23	6,983	23	80	16			
$100+	6,300	21	6,433	21	133	27			
Don't know	4,013	13	4,094	14	81	16			
Missing			389		389				

Variable	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**df**	**chi**	**p-value**
Residential Instability	-0.070 0.209	-0.029	-0.070 0.209	-0.029	-0.070 0.210	-0.069	30673	-0.0294	0.977
Material Deprivation	-0.006 0.187	0.012	-0.006 0.186	0.012	-0.006 0.176	0.012	30673	-0.4454	0.656
Dependency	0.092 0.285	0.121	0.092 0.285	0.121	0.082 0.282	0.121	30673	1.1070	0.268
Ethnic Concentration	-0.350 0.345	-0.477	-0.350 .345	-0.477	-0.353 0.341	-0.477	30673	0.2630	0.793

Table I.3. Characteristics of study sample before and after excluding participants with missing data, including missing outcome information on past-month cannabis use.

	Sample with complete data at baseline (n=29,398)		**Original sample** (n=30,675)		**Excluded due to missing data** (n=1,277)				
Variable	**n**	**%**	**n**	**%**	**n**	**%**	**df**	**chi**	**p-value**
Gender							1	58.67	<0.001
Female	14,536	49	14,852	49	316	36			
Male	14,862	51	15,417	51	555	64			
Missing			406		406				
Grade							3	14.50	0.002
9	8,318	28	8,618	28	300	33			
10	7,895	27	8,144	27	249	28			
11	7,107	24	7,290	24	183	20			
12	6,078	21	6,249	21	171	19			
Missing			374		374				
Race							4	154.70	<0.001
White	19,572	67	20,049	66	477	49			
Black	1,867	6	1,983	7	116	12			
Asian	2,572	9	2,677	9	105	11			
Latinx	1,413	5	1,457	5	44	5			
Other	3,974	14	4,197	14	223	23			
Missing			312		312				

Weekly Spending money									
Zero	5,278	18	5,449	18	171	19	4	18.53	0.001
$1-$20	7,136	24	7,327	24	191	22			
$21-$100	6,815	23	6,983	23	168	19			
$100+	6,212	21	6,433	21	221	25			
Don't know	3,957	13	4,094	14	137	15			
Missing			389		389				
Variable	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**df**	**chi**	**p-value**
Residential Instability	-0.070 0.209	-0.029	-0.070 0.209	-0.029	-0.079 0.210	-0.069	30673	1.505	0.132
Material Deprivation	-0.007 0.187	0.012	-0.006 0.186	0.012	-0.003 0.176	0.012	30673	-0.629	0.530
Dependency	0.093 0.285	0.121	0.092 0.285	0.121	0.073 0.282	0.121	30673	2.493	0.013
Ethnic Concentration	-0.350 0.345	-0.477	-0.350 .345	-0.477	-0.335 0.341	-0.477	30673	-1.576	0.115

Table I.4. Characteristics of study sample before and after excluding participants with missing data, including missing outcome information on past-month cigarette use.

	Sample with complete data at baseline (n=29,617)		**Original sample** (n=30,675)		**Excluded due to missing data** (n=1,058)				
Variable	**n**	**%**	**n**	**%**	**n**	**%**	**df**	**chi**	**p-value**
Gender							1	40.06	<0.001
Female	14,612	49	14,852	49	240	37			
Male	15,005	51	15,417	51	412	63			
Missing			406		406				
Grade							3	14.83	0.002
9	8,382	28	8,618	28	236	35			
10	7,976	27	8,144	27	168	25			
11	7,152	24	7,290	24	138	20			
12	6,107	21	6,249	21	142	21			
Missing			374		374				
Race							4	139.28	<0.001
White	19,688	66	20,049	66	361	48			
Black	1,898	6	1,983	7	85	11			
Asian	2,594	9	2,677	9	83	11			
Latinx	1,427	5	1,457	5	30	4			
Other	4,010	14	4,197	14	187	25			
Missing			312		312				

Weekly Spending money									
Zero	5,311	18	5,449	18	138	21	4	18.80	0.001
$1-$20	7,190	24	7,327	24	137	20			
$21-$100	6,859	23	6,983	23	124	19			
$100+	6,267	21	6,433	21	166	25			
Don't know	3,990	13	4,094	14	104	16			
Missing			389		389				
Variable	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**df**	**chi**	**p-value**
Residential Instability	-0.070 0.209	-0.029	-0.070 0.209	-0.029	-0.075 0.212	-0.069	30673	0.6872	0.492
Material Deprivation	-0.006 0.187	0.012	-0.006 0.186	0.012	-0.003 0.172	0.012	30673	-0.5931	0.553
Dependency	0.093 0.285	0.121	0.092 0.285	0.121	0.075 0.286	0.121	30673	2.0315	0.042
Ethnic Concentration	-0.350 0.345	-0.477	-0.350 .345	-0.477	-0.340 0.342	-0.477	30673	-0.9613	0.336

Table I.5. Characteristics of study sample before and after excluding participants with missing data, including missing outcome information on past-month e-cigarette use.

	Sample with complete data at baseline (n=29,430)		**Original sample** (n=30,675)		**Excluded due to missing data** (n=1,245)				
Variable	**n**	**%**	**n**	**%**	**n**	**%**	**df**	**chi**	**p-value**
Gender							1	16.37	<0.001
Female	14,556	50	14,852	49	296	35			
Male	14,874	50	15,417	51	543	65			
Missing			406		406				
Grade							3	35.94	<0.001
9	8,326	28	8,618	28	292	34			
10	7,920	27	8,144	27	224	26			
11	7,108	24	7,290	24	182	21			
12	6,076	21	6,249	21	173	20			
Missing			374		374				
Race							4	103.17	<0.001
White	19,589	67	20,049	66	460	49			
Black	1,867	6	1,983	7	116	12			
Asian	2,577	9	2,677	9	100	11			
Latinx	1,411	5	1,457	5	46	5			
Other	3,986	14	4,197	14	211	23			
Missing			312		312				

Weekly Spending money									
Zero	5,266	18	5,449	18	183	21	4	26.58	<0.001
$1-$20	7,141	24	7,327	24	186	22			
$21-$100	6,833	23	6,983	23	150	18			
$100+	6,228	21	6,433	21	205	24			
Don't know	3,962	13	4,094	14	132	15			
Missing			389		389				
Variable	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**Mean, SD**	**Median**	**df**	**chi**	**p-value**
Residential Instability	-0.070 0.209	-0.029	-0.070 0.209	-0.029	-0.077 0.211	-0.069	30673	1.1740	0.240
Material Deprivation	-0.006 0.187	0.012	-0.006 0.186	0.012	-0.006 0.173	0.012	30673	-0.0266	0.979
Dependency	0.093 0.285	0.121	0.092 0.285	0.121	0.074 0.286	0.121	30673	2.2164	0.027
Ethnic Concentration	-0.350 0.345	-0.477	-0.350 .345	-0.477	-0.340 0.341	-0.477	30673	-1.0098	0.313

Appendix J: Study Ethics Approval

Notification of Approval (Renewal)

Date:	March 22, 2023
Renewal ID:	Pro00099672_REN3
Principal Investigator:	Roman Pabayo
Study ID:	Pro00099672
Study Title:	Public Health in a time of Austerity: measuring the divestments in Ontario's public health system and evaluating their impacts on population health and health inequities
Sponsor/Funding Agency:	CIHR - Canadian Institutes for Health Research CIHR

RSO-Managed Funding:

Project ID	Title	Grant Status	Sponsor	Project Start Date	Project End Date	Purpose	Other Information
RES0049345							

Approval Expiry Date: March 21, 2024

Thank you for submitting this renewal application. Your application has been reviewed and approved.

This re-approval is valid for one year. If your study continues past the expiration date as noted above, you will be required to complete another renewal request. Beginning at 30 days prior to the expiration date, you will receive notices that the study is about to expire. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the REB does not constitute authorization to initiate the conduct of this research. The Principal Investigator is responsible for ensuring required approvals from other involved organizations (e.g., Alberta Health Services, Covenant Health, community organizations, school boards) are obtained, before the research begins.

Sincerely,

Mary-Jane Sykes, REB Specialist, on behalf of

Theresa Garvin, Ph.D, MUA, BA
Chair, Research Ethics Board 1

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Notification of Approval

Date:	April 21, 2020
Study ID:	Pro00099672
Principal Investigator:	Roman Pabayo
Study Title:	Public Health in a time of Austerity: measuring the divestments in Ontario's public health system and evaluating their impacts on population health and health inequities
Approval Expiry Date:	April 20, 2021
Approved Consent Form:	**Approval Date** 2020-04-21 **Approved Document** Consent Form
Sponsor/Funding Agency:	CIHR - Canadian Institutes for Health Research CIHR

RSO-Managed Funding:

Project ID	Project Title	Speed Code	Other Information
RES0049345	Public Health in a time of Austerity: measuring the divestment in Ontario's public health system and evaluating their impacts on population health and health inequities		

Thank you for submitting the above study to the Research Ethics Board 1. Your application, including the following, has been reviewed and approved on behalf of the committee:

- Recruitment Letter, Version 2, April 20, 2020;
- Complete Instrument for Interview Questions, Version 1, April 10, 2020;
- Proposal, Version 1, April 10, 2020.

Any proposed changes to the study must be submitted to the REB for approval prior to implementation. A renewal report must be submitted next year prior to the expiry of this approval if your study still requires ethics approval. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the Research Ethics Board does not encompass authorization to access the staff, students, facilities or resources of local institutions for the purposes of the research.

Approval by the Research Ethics Board does not encompass authorization to recruit and/or interact with human participants at this time. Researchers still require operational approval (e.g., Alberta Health Services) and must meet the requirements imposed by the public health emergency (link to Alberta COVID page).

Sincerely,

Anne Malena, PhD
Chair, Research Ethics Board 1

Note: This correspondence includes an electronic signature (validation and approval via an online system).