AN ASSESSMENT OF PROVINCIAL POLICY AND YOUTH VAPING RATES IN ALBERTA

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DEDICATION

To my sweet Riley, may you always dream big.

ABSTRACT

To date, no research has examined the impact of the new youth vaping policy in Alberta which was implemented July 2021. The purpose of this study was to examine changes in youth vaping and purchasing patterns in Alberta following the new legislation. Cross-sectional data collected before and after the policy's implementation were compared. Additionally, differences between sex, gender, and grade level were evaluated.

Cross-sectional data were obtained through two cycles of the Canadian Student Tobacco Alcohol and Drugs Survey from students in grades 7 through 12 in 2018/19 and 2021/22 (pooled n = 15,578). The samples were weighted to represent youth in Alberta in each period. Changes in vaping prevalence and underage purchases between survey waves were analyzed using proportions and logistic regression models adjusted for confounders.

In Alberta, there was a 5.1% reduction in the prevalence of youth vaping following 2021 legislation to restrict this activity. The weighed proportion of students who vaped decreased from 19.9% in 2018/19 to 14.8% in 2021/22. After adjustment for confounders, there was a statistically significant reduction on past 30-day vape use between survey waves (OR: 0.65, 99% CI: 0.56–0.76). This decrease was more pronounced in males and students in grades 10–12. In 2018/19, 12.6% of youth purchased vape products underage and this slightly increased to 13.3% in 2021/22, however, these changes, including stratification by sex/gender, were not statistically significant.

There was a statistically significant decline in youth vaping between survey waves, particularly among older youth and males, during the introduction of a new prevention policy. However, unmeasured factors such as societal trends and cultural norms may have also played a role.

CONTRIBUTION OF AUTHORS

Amanda Hepp, Master of Science student, was the primary author of this thesis. A condensed version of Chapter 2 was submitted for publication. For this chapter, the thesis committee members contributed more extensively compared to the other chapters. Throughout the whole thesis, the committee members provided guidance on dataset selection, advised on appropriate analysis strategies, and made suggestions on areas requiring further depth or additional attention. Cheryl Currie reviewed the analysis STATA files from Chapter 2. The entire committee also provided feedback on grammar, writing, and the overall structure of the thesis.

USES OF GENERATIVE AI

1. **Writing Assistance**: Generative AI was used to support the editing of certain sections, providing paraphrasing and grammar suggestions.
2. **Brainstorming Analytical Approaches**: Generative AI was used to compare different analytical strategies and methodologies. All final decisions regarding analysis were made independently.

   The AI was not used to generate original hypotheses, write, plan research, or analyze data.

PREFACE

Data used for this research were taken from Health Canada's Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS), which was conducted for Health Canada by the Propel Centre for Population Health impact at the University of Waterloo 2018-2019 and CCI Research Inc. in 2021-2022 (1,2). Health Canada has not reviewed, approved, nor endorsed this research. Any views expressed or conclusions drawn herein do not necessarily represent those of Health Canada.

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To my husband, Brad—thank you for your support, patience, and love. This achievement would have been so much harder without you by my side. To Riley, my sweet toddler, thank you for being the brightest light in my life. If I hadn't spent so many evenings unwinding with 90 Day Fiancé and other reality TV after you went to bed, I might have finished a semester earlier, but every moment was worth it.

Finally, to my family and friends, thank you for your constant encouragement and belief in me. Your support has meant the world to me throughout this journey.

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LIST OF ABBREVIATIONS

CSTADS	Canadian Student Tobacco Alcohol and Drugs Survey
TSVRA	Tobacco, Smoking and Vaping Reduction Act
SES	Socioeconomic status
TVPA	Tobacco and Vaping Products Act
DAG	Directed Acyclic Graph
E-Cigarette	Electronic cigarette
QALY	Quality-adjusted life years

CHAPTER 1: INTRODUCTION

Electronic cigarettes (e-cigarettes) were initially introduced in the mid-2000s as a tool to help adults quit smoking (3). E-cigarette use, also known as vaping has gained popularity among adolescents, leading to nicotine dependence and significant health concerns (3). These include effects on brain development, cognitive and mood changes, psychosocial health issues, nicotine overdose, and physical risks such as injury from battery explosions (4). Vaping among Canadian youth aged 15 to 19 has risen dramatically, reaching 36% in 2019, marking a significant public health crisis (5). Although a slight decline has occurred in recent years, the persistently high rates have prompted urgent legislative action at both federal and provincial levels to address this growing concern. The Government of Alberta implemented its own vaping reduction legislation in July 2021, and there is currently no peer reviewed research investigating potential impacts in the province (6).

Summary of Research Objectives

This thesis had five objectives within two research papers.

Paper 1: In my first paper, I examined the prevalence of youth vaping in Alberta before and after the Tobacco, Smoking and Vaping Reduction Act (TSVRA) was introduced to reduce vaping in the province (objective 1). Additionally, I tested if sex and gender differences, and grade level were associated with vaping prevalence (objectives 2 & 3).

Paper 2: In my second paper, I examined the prevalence of underage vape purchases at retailer stores before and after the new policy implementation (objective 4). I also evaluated if sex/gender was associated with underage purchases (objective 5).

1.1 METHODS

Study Design

My thesis utilized a serial cross-sectional design, which is used to infer changing patterns over time (7). I compared vaping prevalence and retail purchases among youth in Alberta who completed the 2018/2019 Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS, n = 6,318), to same-aged youth who completed the 2021/2022 CSTADS (n = 9,260) (8,9). These surveys gather data at multiple points across a longitudinal timeline, with each wave sampling a new cohort from the same population.

Sampling Frame

The sampling frame for the surveys included eligible schools with at least 20 students per grade (7–12) (1). The full set of inclusion and exclusion criteria for the primary surveys (which provided data for this secondary analysis) can be found in Table 1. A stratified single-stage cluster design was used, stratifying by health region and school type. Each provincial sampling frame defined two to three health regions, and two categories based on school level. Additionally, a separate category was defined for larger urban centres, encompassing Edmonton and Calgary in Alberta. While the broader surveys included all provinces, respondents from outside of Alberta were excluded for this thesis.

Setting

Data were collected within schools during a class period (1). Teachers were in the room and were told not to circulate during the questionnaire to maintain anonymity. Students were then instructed to place their completed questionnaires in a sealable envelope for collection by a fellow student.

Participants and Data Collection

The target population of the CSTADS consisted of all Canadian residents enrolled in public, private, and Catholic schools in grades 7–12 (1). Students were administered the paper questionnaire if they had parental permission or were of age to consent and were enrolled in an eligible class. They were given the opportunity to decline participation on the day of the survey. The response rate for the 2018/2019 survey in Alberta was 62%, with 6,318 completed questionnaires out of 10,202 eligible students (1). Non-response can be attributed to parent/guardian refusals, student refusals, or absenteeism the day of implementation (1). A combination of active and passive permission methods were used, with school boards and schools determining the most appropriate method to obtain parental consent (1).

Table 1.1: Inclusion and exclusion criteria for the CSTADS

Inclusion Criteria	**Exclusion Criteria**
Grades 7–12 classes within participating school	Located in the Yukon, Northwest Territories, and Nunavut
Students enrolled in any grade 7–12 classes within a participating school	Schools with fewer than 20 students enrolled in any eligible grade
Provided informed consent	Schools for visually impaired
Public, catholic, and private schools	Schools for hearing-impaired
	Schools for special needs students
	Schools in Indigenous Communities
	Virtual schools
	Schools located on a military base

Variables

Outcome: Change in Vaping Prevalence

The first outcome in my thesis is the prevalence of past 30-day vape use. In 2018/19 students were asked on an ordinal scale how frequently they vaped in the previous thirty days

(1). A binary variable was created to classify the students based on their vaping behaviour: 'yes' for those who reported vaping in the past 30 days and 'no' for those who did not. In the 2021/22 survey, three questions on frequency were asked on vaping with nicotine, without nicotine, or with unknown (e.g. with or without nicotine).

A second binary variable of past 30-day use in 2021/22 was determined by dividing the number of students who used an e-cigarette (regardless of nicotine content) by the total number of students with a valid response for the variable. It is important to note that a single student might have used multiple types of e-liquids within the past 30 days (e.g., both with and without nicotine). To avoid counting these students' multiple times, individual estimates were not added together. Although a recent systematic review did not highlight a standardized method for measuring vaping prevalence, the framing of this question (past 30-day use) is consistent with other Canadian surveys (10–13) and other methods used to assess smoking status (14). All variables were merged and combined into one dataset for the secondary analysis. The specific questions and response options can be found in Appendix 1.

Outcome Variable: Vape Source

The second main outcome of my thesis is underage purchases at retail stores. Students were asked about how they obtain their vaping products and self-reported purchase of vape products from a retail store (i.e. convenience store or vape shop). In 2018/19 surveyors asked a single question about source of the vape devices and e-liquids, while in 2021/22 this was split into two questions to capture more details, as seen in Appendix 2.

To measure vape purchases, I created a dichotomous variable indicating self-reported retail store purchases. Options "I buy them from a vape shop” and "I buy them from a convenience store" were coded as 1, while all other options were coded as 0, excluding those do not vape (1) and those who did not answer (99). This decision was made as the policy explicitly prohibits the sale of vapes to minors, meaning that individuals under the age of 18 should not have access to buy these products at retail stores.

Both vape shops and convenience stores are acknowledged as retailers by Public Health Inspectors and Tobacco/Smoking/Vaping Investigators who are among those responsible for inspecting these establishments (15). Other response options for this question, such as online purchases, are not subject to the policy's regulations. Regrettably, Health Canada eliminated the age variable to safeguard the confidentiality of participants (1). Grade levels served as a proxy for age, as 95% of youth fall within the expected age range for their respective grade (i.e., grade 7: 12-13, grade 8: 13-14, grade 9: 14-15, grade 10: 15-16, grade 11: 16-17, and grade 12: 17-18). Individuals in grade 12 were excluded from the analyses in Chapter 3 as they may have been of legal age to purchase vaping products in Alberta.

Exposure: Vaping Policy Change

The exposure in this study is the introduction of the Tobacco, Smoking and Vaping Reduction Act (TSVRA) and Regulation in Alberta July 2021. I compared a survey on student vaping behaviours among Alberta youth in 2018/19 to a comparable survey conducted beginning in the fall of 2021 after the new vaping policy was enacted in the province. A binary variable was created where respondents from 2018/19 were coded as 0 (pre-policy) and respondents from 2021/22 were coded as 1 (post-policy).

Sex and Gender

Health Canada collected data on both sex at birth and gender identity. In 2018/19, the sex at birth variable was provided in the public dataset while in 2021/22 sex at birth was removed and gender was provided. This made it difficult to compare between survey waves. Ultimately, I removed 6.5% of respondents in the recent survey who selected "another gender or gender not stated" from the recent wave to make it comparable. This is why I am referring to the variable as sex/gender. This is important because research has found that LGBTQ+ individuals have higher odds of e-cigarette use (16).

A study by García-Ramírez et al. evaluated California's T21 policy, which raised the minimum purchasing age from 18 to 21 (17). The study revealed greater reductions in lifetime e-cigarette use and lifetime use of any tobacco product among sexual minority youth compared to their non-sexual minority peers (17). Johnson et al. found that transgender and sexual minority youth were more likely to use tobacco products than their nonminority peers in Wave 3 of the U.S. Population Assessment of Tobacco and Health cohort study (18). This suggests that certain subgroups may benefit more from different interventions. However, without detailed data on these groups, it is difficult to implement targeted interventions that effectively address their specific needs and tighten the heath inequity gap.

Covariates

Confounding occurs when a third variable is influencing the apparent association between an exposure and outcome (19). This could create, reinforce, or diminish a correlation that is not directly affected by a genuine association. Identifying potential confounders is crucial in the study design phase to ensure these variables are included in collection. A confounding variable must be associated with the outcome, related to the exposure, and not part of the causal pathway between exposure and outcome. Positive confounding exaggerates the unadjusted association when compared to the adjusted one, while negative confounding weakens the apparent association.

To assess if a variable qualifies as a confounder, I first determined if it was related to both the exposure and the outcome in the study (19). Next, I compared the exposure-outcome association in the crude analysis to the associations with the potential confounder and after adjusting for it. If the direction or magnitude of the association changes significantly, the variable may be considered a confounder.

Variables selected for consideration as confounders include sex/gender, grade level, median household income (as an indicator of socioeconomic status [SES]), smoking status, and urban status. Parental smoking has been identified as a risk factor for adolescent smoking and vaping (20). Unfortunately, data were not collected on this variable. Participants self-reported their grade level and gender. Median household income was ascertained using the school's postal code (1). Specifically, the first three digits of the postal code were matched with the 2016 Canadian Census data on median household income, subsequently rounded to the nearest $5000. Smoking status was a derived variable with 3 levels: current smoker, former smoker, or never smoker (1).

Urban schools were those located within 20 kilometres of Calgary or Edmonton (1). To derive the urban variable, the school's postal code was matched to its Statistics Canada Census Dissemination Area. Participants in a census metropolitan area and tracked or non-tracked census agglomeration were coded as urban, while the remaining categories were coded as rural. Statistics Canada states that rural areas are villages or small towns with less than 1,000 population (21). The survey design does not align with this definition, as communities with fewer than 1,000 individuals likely have class sizes smaller than 20 students and were therefore excluded. Consequently, the "rural" participants in the survey may not be genuinely representative of rural Alberta.

A 2023 systematic review investigated prevalence, change in prevalence, or incidence of youth vaping (10). Age, sex, and SES were among the confounders considered in the review. A study by Nguyen examined shifts in past 30-day e-cigarette use among youth in the CSTADS and identified grade, gender, urban status, aboriginal status, and median household income level as confounding variables (11). The identified potential confounders in this proposal are based on *a priori* findings (11). Controlling for the covariates during analysis enhances the internal validity of the study.

A Directed Acyclic Graph (DAG) is a visual representation which illustrate causal relationships between variables, helping researchers to model causal structures in data (22). Two proposed DAGs for Chapter 2 are outlined in Figure 1. The theorized DAG for Chapter 3 is found in Figure 2. While the policy includes conditions for youth, such as prohibiting minors from possessing, consuming, or using tobacco or vaping products, much of the legislation focuses on regulating the facilities that distribute these products. The term access was chosen as it accounts for the mechanisms in which youth obtain vaping products. Confounders should be associated with both the exposure (policy) and outcomes; however, the identified confounders are not directly related to the policy but do influence how youth access products. I tested the assumptions underlying the potential confounding pathways identified in each.

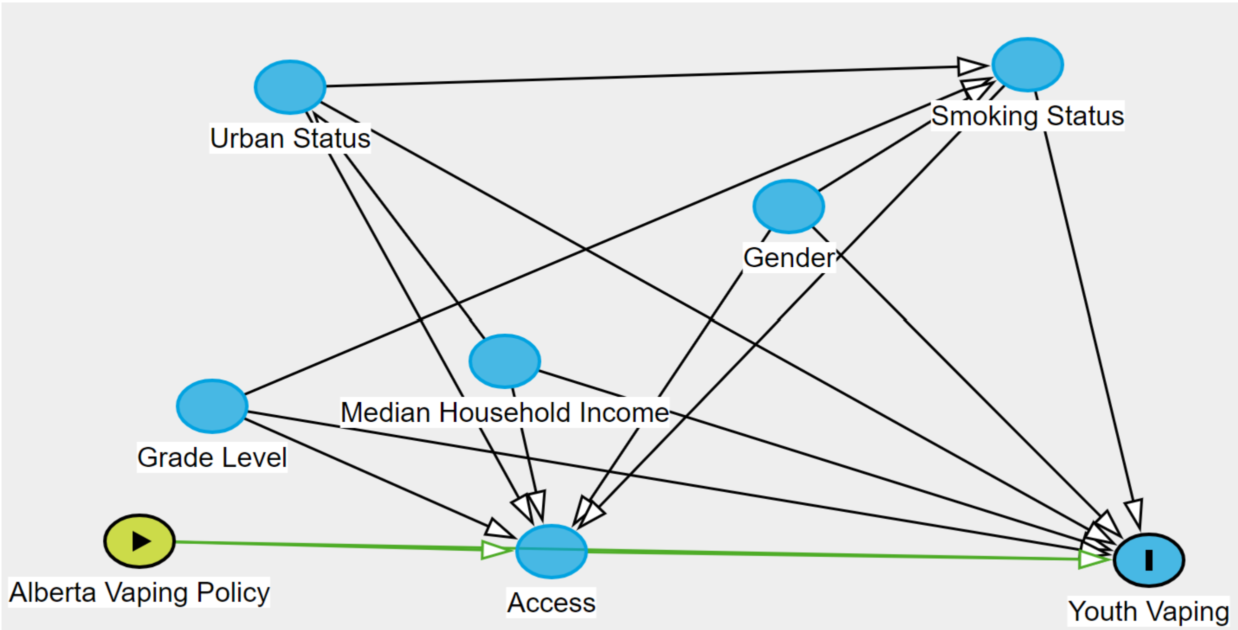

Figure 1: DAGs displaying theorized confounding effects in the relationship of objective 1

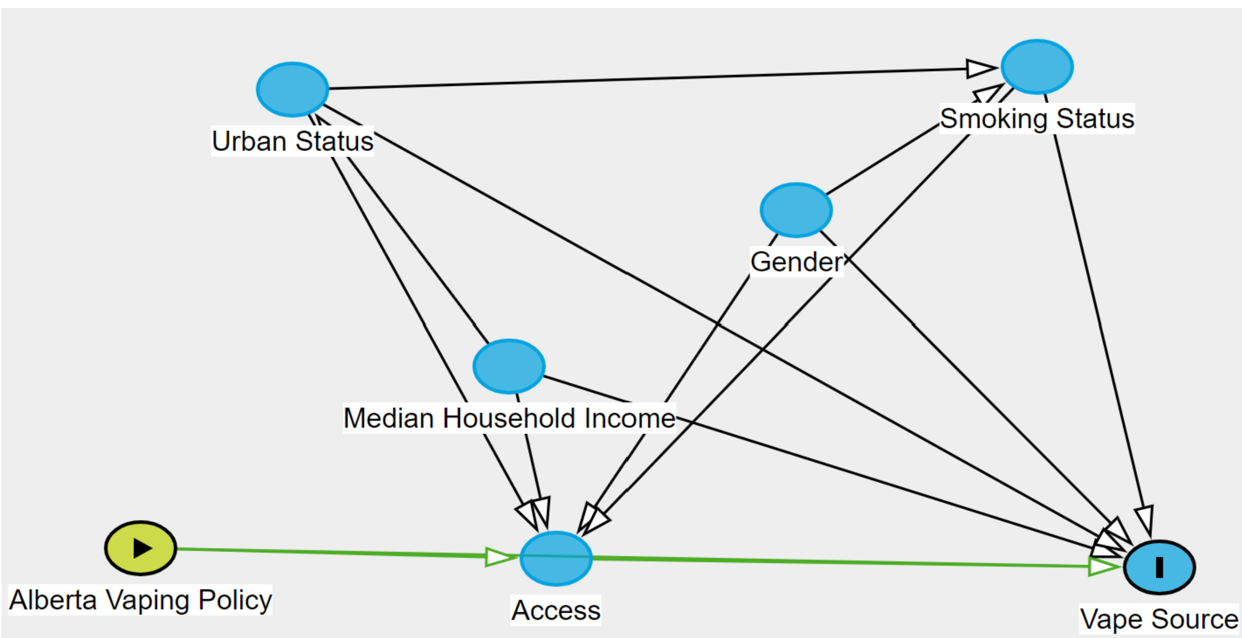

Figure 2: DAG displaying theorized confounding effects in the relationship of objective 4

Bias and Limitations

Observational studies are more susceptible to bias and confounding due to their inability to control for all potential variables that may influence the outcome of interest (23). Selection bias can occur when selection is influenced by factors affected by the exposure or outcome variables, or by their causes (24). To mitigate potential selection bias, the survey designers implemented key considerations. Schools with fewer than 20 students enrolled in any eligible grade were excluded from the sampling frame (1). Sample selection was based on school participation rates of elementary and secondary schools using data from previous cycles of the survey, ensuring a minimum sample size to yield generalizable results (1). Once the list of sampled schools for each province was generated, the co-investigator overseeing implementation in that province reviewed the overall distribution of schools to identify potential concerns at the provincial level (1). Teams within each province were tasked with recruiting school boards. Randomly chosen schools were approached for participation (1). To maintain consistency and monitor progress across Canada, permitted staff utilized an online, real-time database.

Misclassification, a type of measurement error, can occur if a variable is missing or assigned to the wrong category (7). To minimize misclassification of the grade variable, data analysts examined instances where the reported grade was inconsistent with the students' school or where a response was missing. In such cases, the response was recoded to the median grade of the class to which the student belonged (1).

While a response rate of 60% is generally considered acceptable for most research studies, Alberta's rate was only slightly above this threshold, potentially introducing some non-response bias (25). The response rate for the 2021/22 survey is not yet publicly available. However, given that response rates in Alberta for the 2014/15 and 2016/17 cycles were 59% and 75%, respectively, it is reasonable to expect that the 2021/22 response rate will be near or above the acceptable threshold (26,27). Underestimation of risky health behaviours may occur due to non-response bias (28). A cross-sectional study of adolescent health revealed that voluntary sampling yielded lower rates of alcohol and tobacco consumption compared to mandatory sampling (28). Youth who did not respond may have been classified as current vape users and/or purchased products from a vape retailer while underage, thereby reducing the true prevalence.

The systematic review by Reiter et al. highlighted that because of the nature of policy assessment, all included studies had an elevated risk of bias (10). Analyzing population-wide policies is challenging because external factors such as cultural norms, shifting product availability, and disruptions from events like COVID-19 can confound results making it difficult to isolate the policy's true impact. The COVID-19 pandemic was a defining point in history that likely influenced vaping behaviours. Although the survey was conducted in person, students were frequently switching between in-person and virtual learning to reduce exposure to the virus during the second period of data collection. This shift may have altered student behaviour. For example, students who vaped socially or obtained their vapes from peers would have reduced opportunities for social vaping, possibly leading to a false negative result.

A 2022 systematic review found that substance use, including e-cigarettes, among adolescents (under 24 years of age) decreased during the pandemic (29). Reduced peer-group gatherings, availability disruption of substances, and increased time spent at home with parents are suggested to have contributed to the observed decline in prevalence (29). These variables, along with other variables that are difficult to quantify were not included in the dataset I used. This susceptibility can potentially compromise internal validity of the study. While efforts were made to address confounding variables during analysis, ensuring the complete identification and accurate measurement of all variables is difficult. Not all identified confounders were available or consistent between survey waves, meaning that residual confounding is a concern.

Generalizability refers to the extent to which the findings observed in a particular study sample are applicable to other populations (7). Sample size considerations occurred during the design stage to assist with generalizability (1). The stratified single-stage cluster design ensured sufficient sample sizes within the strata's and increased precision (1). The minimum class size of 20 may limit generalizability to rural communities. People in rural and remote areas often face increased vulnerability and higher health risks due to various complex issues, such as limited access to resources, social programs, and affordable healthcare services (30). Additional barriers faced by rural residents include difficulty accessing higher education, job opportunities, and technological infrastructure such as high-speed internet.

A limitation lies in the inability to confidently attribute changes in the outcome directly to the intervention and not to external factors (31). A longitudinal interrupted time series quasi-experimental design, which compares differences in outcomes relative to a control group at multiple periods before and after an intervention, offers stronger internal validity compared to the repeat cross-sectional pre-post non-experimental design employed in this project (32). Studies which investigate regulatory impact on youth vaping have mixed results and thus, this thesis may assist building consistency in the literature (10). It is plausible to anticipate that the policy aimed at reducing youth vaping will effectively achieve its intended goal.

Finally, analyzing population-wide policy presents significant challenges. Public policy issues are often complex, multifaceted, and subject to controversy, with no straightforward solutions (33). As a result, objective analysis is crucial for providing an unbiased assessment of information (33). Conducting a study that effectively informs policymakers is inherently difficult due to the complexity of influencing factors, the challenge of controlling for all potential confounders, and the ever-changing nature of societal trends, government priorities, and public behaviours. Many of these factors are often unmeasured or inadequately captured, limiting the ability to draw definite conclusions. This research utilized a publicly available cross-sectional dataset chosen for its accessibility and time efficiency. However, this approach limited the depth of analysis that a longitudinal dataset could have provided, as it primarily compared prevalence rates of different groups of youth at two time points while acknowledging that a population wide legislative intervention had occurred in between.

Analysis Strategy

Given the study's structure as a serial cross-sectional design, the two survey wave data sets were combined into one. Data were cleaned, organized, explored and transformed as the exposure variable, and outcomes required generation. Descriptive statistics were generated to describe the characteristics of the sample. Categorical variables, including prevalence of vaping, underage vape purchases, grade levels, gender, smoking status, and urban status are presented as counts and proportions.

Each research objective was analyzed using logistic regression models as the outcome variables are binary. Logistic regression enabled me to assess whether there was a statistically significant change in the proportion of youth who vape or report purchasing vape products at retailers between survey waves while accounting for covariates. This helped determine whether any observed changes in youth vaping behaviour or purchasing habits could be attributable to the policy or to other influencing factors. Analyses were conducted using Stata SE 18.0 software.

Ethics

Ethics approval was a prerequisite from multiple entities including the University of Waterloo Office of Research Ethics, Health Canada Research Ethics Board, ethics review boards in affiliated provincial institutions, and school board ethics review committees for the 2018/2019

CSTADS project (1). A determination of ethics review requirement from the University of Alberta Ethics Office concluded that ethics approval was not needed for my secondary analysis (Appendix 3). This research did not receive any funding, while the original surveys were funded by Health Canada (1,2).

Thesis Format

My thesis follows a manuscript-based method. Chapter 1 contains details on the thesis along with a literature review. Chapter 2 examines Research Objective 1-3. Chapter 3 examines Research Objectives 4 and 5. A condensed version of Chapter 2 has been submitted for publication in the Health Promotion and Chronic Disease Prevention in Canada: Research, Policy and Practice Journal. Chapter 4 is a non-published discussion that compares and contrasts my findings across Chapter 2 and 3 with the literature.

Project Significance

Saskatchewan was the first province in Canada to enact their own legislation relating to tobacco in 2002 (34). This policy was amended in 2019 to include e-cigarette and vaping related restrictions (34). The Government of the Northwest Territories released a vaping policy in March 2020, and was updated in March 2022 to further strengthen the policy (35,36). Alberta was the final province to introduce its own policy to prevent and protect public health from the harms associated with vaping, particularly among youth. Policymakers are expected to make evidence-based decisions on significant health interventions, and thus, there is a need to close the literature gap that exists relating to the policy in Alberta (32).

Although research concerning the assessment of underage sales in vape shops and underage e-cigarette purchasing exists in the United States, similar studies are lacking in Canada (37–41). A 2023 scoping review examining how underage youth in the US access e-cigarettes in areas with minimum age sales restriction laws discovered that while social supply was more prevalent than commercial avenues, underage youth did report utilizing commercial routes for self-purchasing (41). It is noteworthy that only one study on past 30-day vape use and policy has been conducted in Canada (11). The Canadian Institute of Health Research has stated that structural determinants of health such as the societal context which shapes proximate determinants are understudied (42). Assessing potential impacts of the policy on youth vaping and underage purchases will help inform future public health policies and areas of intervention to curb underage vaping in Alberta.

1.2 LITERATURE REVIEW

E-cigarettes were introduced in the mid-2000s as a tobacco cessation tool (3). A systematic review suggested that the use of e-cigarettes seems less dangerous than combustible cigarettes due to the lack of carbon monoxide and tars (43). Animal studies have demonstrated that aerosols from an e-cigarette exhibits fewer toxic effects on animal lungs than combustible smoke, however, 20 different carcinogenic and teratogenic compound have been found in e-liquids and vapor (44,45). As a result, aerosols from e-cigarettes can damage airway cells, weaken the body's defence against infections, and increase inflammation (46). They may also enhance the virulence of colonizing bacteria, making infections more severe (46). Although animal research exists, there is a lack of data on the long-term health impacts of continued use of e-cigarettes on humans. In this paper, the terms "vape”, or "vaping" will be utilized, while acknowledging that certain literature may refer to these devices as electronic cigarettes (e-cigarettes) or electronic nicotine delivery systems (ENDS). It's important to note that the discussion excludes vaping of cannabis as CSTADS had a separate section on cannabis use.

Young Users

These devices, informally known as vapes, made their way into the hands of youth (4). Use among them has amplified, bringing about immediate and chronic health impacts (3). A longitudinal cohort study (*n* = 5,490) in Southern California found that e-cigarettes are not simply replacing cigarettes but rather that adolescents who would not have used tobacco products otherwise are now engaging in e-cigarette use (47). Youth who use nicotine-containing devices may develop nicotine dependence, which can cause damage to the developing brain (48,49). Lung injury, pneumonia and acute bronchiolitis, are among health impacts on youth (50). Between August 2019 and January 2020 more than 2,600 cases of e-cigarette or vaping product use-associated lung injury reported to the Centers for Disease Control and Prevention (51). Over half of cases were adolescents or young adults 13 to 24 years of age, and nearly 75% were Caucasian (51).

A 2019 survey was distributed to Canadian paediatricians and identified 88 cases of vaping related illness and injury among children aged 0-17 years old (52). The most common clinical presentations were respiratory distress and nicotine toxicity, while some cases involved traumatic injuries, such as burns or facial injuries, relating to device malfunction or modification (52). A 2020 review of the Canadian Consumer Product Safety Program between 2015 to 2019 found a 73% annual increase in vaping related reports received (53). They also found that youth aged 15-19 years had a proportionate injury ratio of 11.5, meaning that this age group was over 11 times more likely to experience vaping-related injuries compared to other age groups (53). Vaping products were added in 2020 to this program as one of the top ten reported product types across Canada (54). In 2021, there were 52 vaping related hazard reports received, of which 56% mentioned injuries and were commonly poisonings or burns (54). Among these injuries, 38%

were classified as severe, 10% as moderate, and 24% as minor while 28% lacked sufficient detail (54). No fatalities were reported.

Youth and young adult vapers in Canada were more likely to have looked for health implications of vaping and nicotine poisoning than their adult counterparts, highlighting their awareness of potential negative consequences (55). Additionally, 30% reported that their classmates vaped, indicating significant exposure to vaping in social settings (55). Research among Canadian youth who vape found that initiation often occur at the encouragement of a close friend or acquaintance (56). This behaviour typically takes place during social gatherings, driven by curiosity and a perception that trying vaping is a low-risk activity (56).

Economic Impacts

The economic implications of e-cigarette regulation remain a critical consideration for public health decision-makers. A cost-utility analysis from the perspective of Canada's publicly funded healthcare system assessed the impact of vaping on health outcomes and healthcare costs (57). This analysis compared three scenarios: unrestricted availability of e-cigarettes, complete elimination, and access restricted to prescription-only for smoking cessation. It found that quality-adjusted life years (QALYs) and smoking-related healthcare costs were negatively impacted under the unrestricted availability scenario, suggesting potential economic benefits of more restrictive e-cigarette policies.

A recent study evaluated the potential long-term economic and health impacts of a proposed Smoke-Free Generation (SFG) policy in Canada, which would theoretically ban tobacco sales to individuals born after 2009, starting in 2025 (58). After 50 years, the policy was expected to generate 476,814 additional QALYS and $2.3 billion in healthcare cost savings. However, it would also result in a $7.4 billion loss in smoking-related tax revenue and a $3.1

billion decline in the tobacco industry’s GDP. Despite these economic trade-offs, the study concluded that the long-term health benefits and healthcare savings outweigh the financial losses, reinforcing the value of upstream policy interventions in tobacco and vaping control.

These findings are supported by a systematic review of 15 modelling studies examining the health and economic impacts of population-level e-cigarette control policies across multiple countries, including Canada (59). While the review found that 11 of the 15 studies concluded net benefits associated with less restrictive policies, limitations related to model structure, data quality, and uncertainty analysis were noted. Importantly, four studies concluded net losses in QALYs or healthcare costs, highlighting the variability in potential outcomes.

Vaping Among Youth

A systematic review and meta-analysis of 11 studies found a longitudinal association among adolescent who vape and future smoking initiation (60). Youth have acknowledged the fruity flavours, convenience, and discreetness of vaping enable them to continuously vape throughout the day in locations that do not allow combustible cigarettes (61). Certain e-cigarettes can deliver higher concentrations of nicotine compared to traditional combustible cigarettes, and these devices can also be tampered with to increase nicotine delivery (62). This leads to a lack of awareness of how much they are consuming (61).

A qualitative study in Colorado exploring youth perspectives on vaping highlighted the ease of concealing the behaviour, noting that it was often perceived as a "status thing," particularly among those who could discreetly vape even under a teacher's supervision (63). The study revealed that youth identified various reasons for vaping, including social connection, peer pressure both to vape and to abstain, stress and emotional management, performing tricks, and the appeal of flavours (63). They also acknowledged the potential consequences of vaping, such as addiction, disciplinary actions, negative health effects, and the perception that it is less harmful than conventional cigarettes (63). A systematic review on e-liquid flavours indicated that both cross-sectional and longitudinal studies highlight the significant role flavours play in initiating and sustaining vaping behaviours, although the overall quality of evidence was low (64).

One study conducted in the United States among adolescents who reported past 30-day use found that over half believed that nicotine in e-juice is artificially made (65). East et al. examined social norms around vaping and smoking in England, Canada, and the United States, finding that peer approval for vaping (44%) was nearly double that for smoking (23%) (66). Additionally, they observed that Canadian youth were more likely than their English or American counterparts to report having friends who vape (66).

Vaping among youth in Canada has increased from 5.7% in 2014/15 to 20.2% in 2018/19 (9,67). Nationally, 21.5% of male youth and 18.9% of female youth reported vaping in 2018/19 (8). However, this trend reversed by 2021/22, with 14.6% of males and 18.6% of females reporting vaping (9). Eastern Canadian provinces tend to have higher youth vaping rates than Western provinces. For example, nearly 27% of youth in Newfoundland were vaping in 2021/22 compared with 16% in British Columbia (9). In recent years, Alberta has fallen below the national average with 14.8% users compared to nearly 16.8% nationally (9).

The perception of the ease with which e-cigarettes can be obtained among underage youth is alarming. Results from the 2018/2019 CSTADS found that over half of Canadian students in grades 7–12 believed that obtaining an e-cigarette would be “fairly easy” or “very easy” (8). A repeat cross-sectional which analyzed seven waves of an international youth tobacco and vaping survey found that over 65% of Canadian youth thought it would be easy to access e-cigarettes (68). These alarming trends have triggered legislative updates at both federal and provincial levels.

Public Policy

Public policy refers to the strategies, actions, and decisions developed by governments at any level to address issues that require a collective response to promote societal well-being and resolve pressing challenges (69). Legislative regulation is a type of public policy that involves creating enforceable rules and standards through formal legal processes. These regulations are designed to govern behaviour, protect public interests, and address societal challenges, often with mechanisms for compliance and penalties for violations (69). Regulations, also called delegated or subordinate legislation, are detailed rules made under the authority of a statute to help implement and enforce laws (70). While the Legislature creates statutes, it delegates authority to other bodies or individuals to develop regulations that govern behaviour, protect public interests, and address societal challenges (70). These regulations ensure compliance through specific standards and may include penalties for violations, as seen in the Tobacco, Smoking and Vaping Reduction Act and Regulation, which are the focus of this study.

Individual behaviour change is inherently challenging, particularly in addressing risk factors for non-communicable diseases (71). Policies often begin by acknowledging the upstream social determinants of health but tend to experience "lifestyle drift," shifting focus downstream toward individual behaviour rather than addressing systemic drivers of inequities (72). Upstream policies, such as the Tobacco, Smoking, and Vaping Reductions Act, aim to create structural conditions that reduce population-level exposure to risk factors like tobacco and e-cigarette use, recognizing that systemic interventions are often more effective than relying on individual behaviour change alone.

Vaping Legislation

In 2023, Reiter et al. conducted a systematic review to compile evidence regarding the efficacy of regulatory measures at both provincial/state and national levels in high-income countries, aimed at reducing youth vaping (10). The review included both randomized and non-randomized studies that provided primary data on the effects of regulatory programs, strategies, or policies implemented by provincial/state or national governments (10). These interventions aimed to prevent or reduce youth nicotine vaping and included at least one specific element designed for this purpose (10). There was not enough evidence to support age restrictions in reducing youth vaping prevalence (n = 16), restrictions on use location (n = 1), or mixed/combined regulations (n = 3) (10). They did however find that sales licenses, flavour bans, and taxation were generally associated with a decreased prevalence of youth vaping (10).

A recent international study by Chan and colleagues examined the association between the implementation of tobacco control policies on adolescent vaping across 44 lower-middle, upper-middle, and high-income countries (73). They found that countries where cigarette taxes make up 75% of the total cost had 2.5 higher odds of past 30-day vaping (i.e. any vape use in the past 30 days) and an impressive 6.1 higher odds of past 30-day frequent vaping (i.e. any vape use in the past 10 or more days), compared to those in countries where taxes account for less than 25% of the cost (73). They also found that the association of tobacco control policies and youth vaping was inconclusive due to significant variation of their impact across countries (73).

Olson and colleagues examined adolescent tobacco use in Minnesota before and after local restrictions on menthol (2018) and other flavoured (2016) tobacco products (74). They found that cities with policies restricting flavoured tobacco products experienced a smaller increase in adolescent tobacco use compared to the rest of state, indicating that policy change may influence youth behaviours (74).

The contrasting trends in youth vaping rates across Canada, the US, and England emphasize the role of regulatory frameworks in influencing behaviour (75,76). Between 2017 and 2018, Hammond et al. reported a sharp rise in vaping prevalence among adolescents in Canada and the US, with significant increases observed even among non-smokers and experimental smokers (75,76). In contrast, England experienced relatively stable vaping rates during the same period, which may be attributed to its more stringent e-cigarette regulations which take a harm reduction approach for cigarette smokers (75,76).

The Tobacco and Vaping Products Act (TVPA) sets federal standards for the production, sale, labelling, and marketing of tobacco and vaping products in Canada (77). While provinces and territories must adhere to the federal legislation, they can also enact their own laws that impose stricter regulations in certain areas such as promotional advertisements, access, and place of use. The federal policy does not specify how age verification of those under 18 years old is carried out (77). Research has shown that in provinces with their own legislation prohibiting access and use, youth had a better perception of the harms, and the prevalence increased but at a statistically slower rate than in provinces without a ban (11).

In 2002, the province of Saskatchewan was first in Canada to introduce a policy to prevent tobacco use for their citizens (34). This legislation was amended in 2019 to include a restriction on e-cigarette sales to minors (34). The Northwest Territories enacted a vaping policy shortly before Alberta. Their regulation was released in March 2020 and has since been updated in 2022 to further attempt reduction in vaping (35,36). Nunavut, as the final territory in Canada to do so, implemented its policy in May 2023 (78).

Alberta is one of the more conservative provinces in Canada, often prioritizing individual autonomy over province-wide restrictions. Prior to the implementation of the TSVRA, advocacy groups such as Campaign for a Smoke-Free Alberta called for stronger vaping regulations to protect youth (79). Alberta's policy was put into effect July 2021 with the aim of safeguarding citizens from the dangers posed by tobacco and vaping products, as well as to tackle the rise in youth vaping (15). The policy established minimum age requirement and mandated government-issued photo identification for purchasing, possessing, and consuming vaping products (6). Additionally, it imposed restrictions on advertisements, displays, and promotional materials, as well as limitations on the locations where vape products can be sold (6).

To ensure widespread awareness and compliance, over 2000 toolkits containing information, employee training resources, guidelines, and support materials were distributed to all retailers selling tobacco and vape products in early 2022 (80). Toolkits were delivered to any stores known to be selling tobacco and/or vaping products including but not limited to convenience stores, gas stations, speciality vape shops, tobacconists, and grocery stores (80).

Impact of policy on youth vaping

The first objective of my thesis is to examine the prevalence of youth vaping before and after the new policy was enacted in Alberta to prevent this behaviour. A systematic review by Reiter et al. included 30 studies investigating policy targeting youth age 12-21 in high-income countries and the prevalence, change in, or incidence of youth vaping (10). Their findings indicate that flavour bans, warning labels, sales licenses, and taxation were associated with a reduction on youth vaping while age restrictions had heterogenous results (10). Yan et al. conducted a systematic review on the impact of global approaches to regulate electronic nicotine products (81). Of the 48 studies included in the review, 10 examined current vape use and minimum age restrictions which yielded mixed results (81). The Ontario Tobacco Research Unit conducted a review on the effectiveness of setting the minimum age for e-cigarette use at 21 and noted the varied conclusions of existing studies, indicating a need for further research (82).

One study in Canada has been done to investigate the impact of policy on youth vaping prevalence (11). The quasi experimental difference-in-differences and triple-differences study in 2019 investigated the extent to which provincial restrictions on e-cigarette sales reduced e-cigarette use (11). Between 2013 and 2017, the prevalence of youth e-cigarette use increased in all provinces but at a statistically slower rate in provinces with legislation prohibiting e-cigarette sales to minors (11). In provinces with legislation, youth had a better perception of the harm associated with e-cigarette use and found it more difficult to acquire e-cigarettes. However, there was also an observed increase in the use of social sources for obtaining e-cigarettes in these provinces (11). Alberta was utilized as a control in this study for comparative analysis, given the absence of such legislation. These findings emphasize the potential impact of public policies aimed at reducing youth access to e-cigarettes by restricting sales to minors. This thesis aims to further investigate and build consistency on the effects of legislation on vaping behaviour among youth, given recent legislative change in Alberta.

Impact of policy on vape purchase by youth

The main objective of Chapter 3 is to examine if the enactment of policy in Alberta reduced underage vape purchases at retail stores. A 2020 cross-sectional study examined the sources of e-cigarette products reported by youth in three high income countries through the first wave of an international tobacco control policy survey (83). Adolescents who reported vaping in the past 30 days were questioned as to the source, revealing that 41.4% obtained their products from a commercial source (83). Of those who reported purchasing vape products, vape shops were the most commonly cited location (83). A cross-sectional survey of U.S. youth aged 13–17 years found that 17.2% obtained their JUUL e-cigarettes, a specific brand, exclusively through personal purchases, with gas stations and convenience stores being the most common purchase locations (84). Pepper et al. conducted an original cross-sectional survey among 15-17 year olds in the United States in 2018 and found that of the 31.1% of youth who reported buying vape devices themselves, 22.3% identified a vape shop or lounge as the location of purchase (85).

In 2019 a national policy was passed in the US which raised the legal age of purchasing tobacco products from 18 to 21 years old (86). A population-based cohort study in Southern California found a decrease in underage purchases at a vape shop between pre-policy and post-policy, however the results were not significant (87). The majority of those under 21 reported that e-cigarettes were harder to buy compared with the year prior (87). A national cross-sectional study in the United States suggest that during the COVID-19 pandemic, vape shops and online platforms were regularly selling vaping products to underage youth (88).

A recent prospective cohort study investigated the act of purchasing e-cigarette products in young adults in Southern California who are under 21 years old and have previously used e-cigarettes (37). Of the 332 underage participants who own and have purchased their own device, over 70% reported buying them at a vape shop or speciality tobacco store as the top source. A qualitative study conducted in Southern California revealed that underage individuals frequently encountered inconsistent enforcement of age restrictions at in-person retail locations (89). These findings indicate that even with a minimum age restriction law, underage purchases are still occurring. Sindelar noted that enforcing bans on e-cigarette sales to minors presents significant challenges, particularly in retail settings (90). Strengthening access restrictions may require increased funding for enforcement initiatives and enhanced collaboration between federal and provincial governments to develop more effective strategies for preventing youth access both in stores and online (90).

In 2018, 24% of underage students purchased tobacco in Alberta while across Canada 38% purchased vape devices from a retailer or online (80). Youth below the legal purchasing age of 18 years are acquiring e-cigarettes in violation of federal law (77). The policy is considered a structural determinant of health which are the larger societal, ecological, economic and political contexts which shape social determinant of health (42).

1.3 IMPLEMENTATION SCIENCE

Implementation research is the scientific study regarding implementation (91). This may relate to any aspect of implementing a new intervention such as factors affecting, process of, or results of implementation (91). It goes beyond measuring outcomes alone, focusing instead on understanding the processes, contextual factors, and barriers or facilitators that influence successful implementation. This approach is particularly valuable in public health, where interventions such as the new policy must operate within complex, dynamic environments. Unlike controlled experimental studies, such as randomized control trials, implementation research emphasizes external validity ensuring that findings are applicable to broader populations and real-world contexts (92). The timing of intervention rollout is an important consideration in implementation research.

In this study, the vaping policy was implemented simultaneously across the entire province, as mandated by the government, leaving no opportunity for staggered implementation or random allocation (92). This reflects a key principle of implementation research, which, as Peters et al. describe, aims to "understand and work within real-world conditions, rather than trying to control for these conditions or to remove their influence as causal effects" (91). Such conditions highlight the need for research methods that can evaluate intervention effectiveness within the natural complexities of public health practice.

1.4 CONCLUSION

While internal evaluations of the policy may have been conducted, there is currently no peer-reviewed research that investigates possible impact of the new policy in Alberta. This project contributes to the field of implementation science by exploring changes in youth vaping prevalence and underage vape purchases before and after a regulatory intervention was implemented. Additionally, the analyses were stratified by sex/gender and grade level providing key information on subpopulation effects. This approach highlights the real-world trends associated with the policy and provides awareness that can inform future regulatory strategies for youth vaping prevention.

CHAPTER 2: CAN POLICY CHANGE REDUCE YOUTH VAPING? A SERIAL CROSS-SECTIONAL ANALYSIS OF THE 2018/19 AND 2021/22 CANDIAN STUDENT TOBACCO ALCOHOL AND DRUGS SURVEY IN ALBERTA.

Contributions of Authors: Chapter 2 was submitted for publication and is based on collaborative work with Cheryl Currie, James Sanders, and Lars Hallstrom. I conducted all analyses and drafted the original manuscript. Cheryl Currie, James Sanders, and Lars Hallstrom provided valuable feedback, grammar edits, and suggestions to improve the manuscript. Additionally, Cheryl Currie conducted a review of the analysis to ensure its accuracy.

2.1 INTRODUCTION

Background

E-cigarettes were introduced as a tobacco cessation tool for adults in the mid-2000s (3). Due to the lack of carbon monoxide and tars associated with these devices, a systematic review suggested that e-cigarettes seemed less dangerous than combustible cigarettes (43). Animal studies have demonstrated that the aerosols exhibit fewer toxic effects on animal lungs than combustible smoke, however, 20 different carcinogenic and teratogenic compounds have been found in e-liquids and vapor (44,45). As a result, aerosols from e-cigarettes can damage airway cells, weaken the body's defence against infections, and increase inflammation (46). They may also enhance the virulence of colonizing bacteria, making infections more severe (46).

Vaping became popular among adolescents, resulting in nicotine dependence and adverse health impacts including influence on the developing brain, cognitive and mood implications, effects on psychosocial health, nicotine overdose, and physical risks such as injury from battery explosions (3,4). A 2019 survey was distributed to Canadian paediatricians and identified 88 cases of vaping related illness and injury among children aged 0–17 years old (52). The most common clinical presentations were respiratory distress, and nicotine toxicity (52). The 2020 Canadian Consumer Product Safety Program found a 73% increase in vaping related reports received between 2015 and 2019 (53). Vaping products were added in 2020 to this program as one of the top ten reported product types across Canada (54). In 2021, there were 52 vaping related hazard reports received, of which 56% were poisonings or burns (54).

Youth and young adult vapers in Canada were more likely to have looked for health implications of vaping and nicotine poisoning than their adult counterparts, highlighting their awareness of potential negative consequences (55). Additionally, 30% reported that their classmates vaped, indicating significant exposure to vaping in social settings. Initiation of vaping among Canadian youth often occur at the encouragement of a close friend or acquaintance (56). This behaviour typically takes place during social gatherings, driven by curiosity and a perception that trying vaping was a low-risk activity (56). Youth have acknowledged the fruity flavours, convenience, and discreetness of vaping enable them to continuously vape throughout the day in locations that do not allow combustible cigarettes (61).

Vaping among youth in grades 7–12 Canada has increased from 5.7% in 2014/15 to 20.2% in 2018/19 (9,67). Nationally, 21.5% of male youth and 18.9% of female youth reported vaping in 2018/19 (8). However, this trend reversed by 2021/22, with 14.6% of males and 18.6% of females reporting vaping (9). Eastern Canadian provinces tend to have higher youth vaping rates than Western provinces. For example, nearly 27% of youth in Newfoundland were vaping in 2021/22 compared with 16% in British Columbia (9). In recent years, Alberta has fallen below the national average with 14.8% users compared to nearly 16.8% nationally (9). This public health crisis has triggered legislative updates at both federal and provincial levels.

The Tobacco and Vaping Products Act (TVPA) sets federal standards for the production, sale, labelling, and marketing of tobacco and vaping products in Canada (77). While provinces and territories must adhere to the federal legislation, they can also enact their own laws that impose stricter regulations in certain areas. Upstream approaches, such as policy, are known to have a greater impact to change behaviour than downstream approaches, such as education (93). The federal policy governs the manufacture, labelling, sale, and promotion of tobacco and vaping products in Canada, but does not specify how age verification of those under 18 years old is carried out (77). Provincial or territorial legislation tends to be more stringent regarding access, promotion, and place of use. Research has shown that in provinces with their own legislation prohibiting access and use, youth had a better perception of the harms, and the prevalence increased but at a statistically slower rate than in provinces without a ban (11).

In 2002, the province of Saskatchewan was the first province in Canada to introduce a policy to prevent tobacco use for their residents (34). This legislation was amended in 2019 to include a restriction on e-cigarette sales to minors (34). The Northwest Territories enacted a vaping policy shortly before Alberta. Its legislation was released in March 2020 and has since been updated in 2022 to further attempt reduction in vaping (35,36). Nunavut, as the most recent territory in Canada to do so, implemented its policy in May 2023 (78).

Alberta Vaping Policy

The Tobacco, Smoking and Vaping Reduction Act was enacted in Alberta in July 2021. The aim of this policy was to safeguard citizens from the dangers posed by tobacco and vaping products, and address rising youth vaping rates (15). The policy established a minimum age to purchase vape products (18 years) with a requirement to provide government-issued photo identification (6). While the policy includes conditions for youth, such as prohibiting minors from possessing, consuming, or using tobacco or vaping products, the legislation focuses mostly on regulating the facilities that distribute these products (6).

While internal evaluation of the policy may have been conducted, there is currently no peer-reviewed research that investigates the change in prevalence of youth vaping in Alberta after the policy, and little research on the impact of policy on youth vaping in Canada more broadly (11). Internationally, a 2024 systematic review investigating the impacts of policy on youth vaping found insufficient evidence to suggest minimum age restrictions, restrictions on location of use, and combined/mixed regulation to reduce youth vaping (10).They did however find that sales licenses, flavour bans, and taxation were generally associated with decreased prevalence of youth vaping (10).

A recent international study by Chan and colleagues examined the association between the implementation of tobacco control policies on adolescent vaping across 44 lower-middle, upper-middle, and high-income countries (73). They found that the countries where cigarette taxes make up 75% of the total cost had 2.58 higher odds of past 30-day vaping and 6.18 higher odds of past 30-day frequent vaping among adolescents, compared to those in countries where taxes account for less than 25% of the cost (73). They also found that the association of tobacco control policies with youth vaping inconclusive due to significant variation of their impact across countries (73).

Objectives

The main objective of this thesis chapter is to examine youth vaping prevalence in Alberta using two recent waves of the Canadian Student Tobacco Alcohol and Drugs Survey before and after a new legislative intervention was introduced in July 2021. I also examined whether male or female youth would be more likely to change vaping behaviour after the policy was implemented, as well as differences in grade level.

2.2 METHODS

Setting & design

The project utilized a serial cross-sectional design (combined sample $n = 15{,}578$) which is used to infer changing patterns over time (7). These surveys gather data at multiple points across a longitudinal timeline, with each wave sampling a new cohort from the same population (7). This approach allows for the calculation of prevalence rates based on the collected data. Alberta youth in grades 7–12 who completed the Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS, $n = 6{,}318$) between October 2018 and June 2019 formed the pre-policy sample. The post-policy sample were Alberta youth in grades 7–12 who completed the CSTADS between September 2021 and June 2022 ($n = 9{,}260$) (5,9). A stratified single-stage cluster design was used, stratifying by health region and school type (1). Each provincial sampling frame defined two to three health regions, and two categories based on school level and a separate category was defined for larger urban centres, encompassing Edmonton and Calgary in Alberta (1). Data were collected within schools during class periods, and teachers were in the room told not to circulate during the questionnaire to maintain anonymity (1).

Participants

The target population were all students in grades 7–12 who were enrolled in public, private, and Catholic schools (1). Youth were administered the paper questionnaire if they had parental permission or were of age to consent and were enrolled in an eligible class. Schools with fewer than 20 students enrolled in any eligible grade, virtual schools, schools on a military base, schools on Indigenous land, and schools for special needs or hearing or visually impaired were excluded. Students were given the opportunity to decline participation on the day of the survey. A combination of active and passive permission methods was used, with school boards and schools determining the most appropriate method to obtain parental consent.

Survey weights

In complex survey designs like CSTADS, the sample data are multiplied by specific weights that account for varying sampling fractions to generate a representative estimate for the survey population. Without the use of survey weights, one simply derives estimates based on the individuals included in the sample, n, rather than a population estimate of N (1,2). A critical purpose of survey weights is to correct for sampling methods and overall survey nonresponse (2). Ideally, if every person in a population had an equal chance of being selected and participated in the survey equally, all cases would have the same survey weight, reflecting the inverse probability of selection and response. However, due to the more complex sampling methods used in CSTADS and the uneven nonresponse rates, not all individuals had an equal chance of participating. Both the 2018/19 and 2021/22 surveys included pre-calculated survey weights, determined by researchers at Health Canada (1,2). Raw counts were analyzed without applying weights, while all regression models and proportion estimates were generated using survey weights.

Variables

Outcome: vaping prevalence

The main outcome in this study is the prevalence of past 30-day vape use among Alberta youth in grades 7–12. In 2018/19 students were asked on an ordinal scale how frequently they vaped in the previous thirty days. A binary variable was created to classify the students based on their vaping behaviour: 'yes' for those who reported vaping in the past 30 days and 'no' for those who did not. In the 2021/22 survey, three questions on frequency were asked on vaping with nicotine, without nicotine, or with unknown substance (i.e., student does not know if the product contains or does not contain nicotine).

A second binary variable of past 30 days use in 2021/22 was determined by dividing the number of students who used an e-cigarette (regardless of nicotine content) by the total number of students with a valid response for the variable. It is important to note that a single student might have used multiple types of e-liquids within the past 30 days (e.g., both with and without nicotine). To avoid counting these students' multiple times, individual estimates were not added together. Although a recent systematic review did not identify a standardized method for measuring vaping prevalence, the framing of this question (past 30-day use) is consistent with other Canadian surveys and other methods used to assess smoking status (10–14). The variables were merged and combined into one dataset for the secondary analysis. The specific questions and response options can be found in Appendix 1.

Exposure: vaping policy change

The exposure in this study is the introduction of the Tobacco, Smoking and Vaping Reduction Act in Alberta in July 2021. I compared a survey on past 30-day vaping among Alberta youth in 2018/19 to a similar survey conducted beginning in the fall of 2021. This survey was conducted after the new vaping policy was enacted in the province. A binary variable was created where respondents from 2018/19 were coded as 0 (pre-policy) and respondents from 2021/22 were coded as 1 (post-policy).

Sex and gender

Research has found that LGBTQ+ individuals have higher odds of e-cigarette use (16). Health Canada collected data on both sex at birth and gender identity. In 2018/19, the sex at birth variable was provided in the public dataset while in 2021/22 Health Canada removed sex at birth and provided gender. This made it difficult to compare between survey waves. Ultimately, I removed 6.5% of respondents in the recent survey who selected “another gender or gender not stated” from the recent wave to make it comparable. This is why the variable is referred to as sex/gender. Without detailed data, one cannot consider targeted interventions to address the specific needs of LGBTQ+ individuals, who face additional health inequities and systemic discrimination.

Grade level

In 2018/19, 9.8% of youth vaped in grades 7–9, while 30.4% among those in grades 10–12 vaped, a significant difference between younger and older adolescents (8). Students self-reported their grade level. A new variable was created and values from the 2018/19 survey’s grade variable were assigned for respondents from that wave. Similarly, values from the 2021 survey’s grade variable were assigned for respondents from the later wave. The process ensured that all respondents were assigned a valid grade level based on their survey year in a single variable for analysis.

Confounders

Variables selected for consideration as confounders include sex/gender, grade level, median household income (as an indicator of socioeconomic status [SES]), smoking status, and urban status. Participants self-reported their grade level and gender. Median household income was ascertained using the school’s postal code (1). Specifically, the first three digits of the postal code were matched with the 2016 Canadian Census data on median household income, subsequently rounded to the nearest $5000. Smoking status was a derived variable with 3 levels: current smoker, former smoker, or never smoker (1).

To derive the urbanicity variable, the school's postal code was matched to its Statistics Canada Census Dissemination Area. Participants located within 20 kilometres of Calgary or Edmonton were coded as urban while the remaining categories were coded as rural (1). Statistics Canada states that rural areas are villages or small towns with less than 1,000 population (21). The survey design does not align with this definition, as communities with fewer than 1,000 individuals likely have class sizes smaller than 20 students and were therefore excluded. Consequently, the "rural" participants in the survey may not be genuinely representative of rural Alberta.

Bias

To mitigate potential selection bias, the survey designers implemented key considerations. Schools with fewer than 20 students enrolled in any eligible grade were excluded from the sampling frame (1). Sample selection was based on school participation rates of elementary and secondary schools using data from previous cycles of the survey, ensuring a minimum sample size to yield generalizable results. Once the list of sampled schools for each province was generated, the co-investigator overseeing implementation in that province reviewed the overall distribution of schools to identify potential concerns at the provincial level. Teams within each province were tasked with recruiting school boards. Randomly chosen schools were approached for participation. To maintain consistency and monitor progress across Canada, permitted staff utilized an online, real-time database.

Misclassification, a type of measurement error, can occur if a variable is missing or assigned to the wrong category (7). To minimize misclassification of the grade variable, data analysts examined instances where the reported grade was inconsistent with the students' school or where a response was missing. In such cases, the response was recoded to the median grade of the class to which the student belonged (1).

Sample size

Sample size considerations occurred during the design stage to assist with generalizability (1). The stratified single-stage cluster design ensured sufficient sample sizes within the strata and increased precision (1). The initial sample sizes were 6,318 for the 2018/19 survey and 9,260 for the 2021/22 survey. In 2018/19, 90 students (1.4%) did not answer the past 30-day vape use question. For the 2021/22 questions on vape use with nicotine, without nicotine, and unknown, 197, 365, and 372 students respectively (2.13%, 3.94%, 4.02%) did not answer the survey questions. Missing data were removed using listwise deletion, as the amount of missing data were negligible (<5%), ensuring that the remaining sample size was sufficiently large to provide reliable estimates. The final sample sizes were 6,157 and 9,000 respectively.

Statistical methods

Sample characteristics were examined using unweighted counts and proportions. Weighed odds ratios and 99% confidence intervals examined the change in vaping prevalence before and after youth were exposed to the policy change. Logistic regression is widely used in epidemiological research, where outcomes often have only two possible values, such as the presence or absence of a behaviour, or whether a particular event occurred during a specified time frame (94). It helps model the probability of these binary outcomes based on one or more predictor variables.

Ten models were conducted including one unadjusted model to predict the odds of vaping post-policy and one model adjusted for both grade level and sex/gender. Stratified analyses were also performed for males, females, grades 7–9, and grades 10–12. For each subgroup, an unadjusted model was first run, followed by an adjusted model controlling for the relevant confounder (grade level for sex/gender stratifications and sex/gender for grade-level stratifications). This approach allowed for both unadjusted and adjusted assessments of the change of vaping prevalence across different subgroups. All analyses were performed using STATA/SE 18.0. Log files documenting the creation of Table 2.1 and 2.2 are available upon request.

Normality

To test if the models have a normal distribution of errors, the linktest was run. The _hat was statistically significant, signifying the model is a good fit. Hatsq was omitted because of collinearity. The Hosmer-Lemeshow test was also run and found to have significant result, indicating a lack of fit for the model. However, it is important to note that this test has several limitations, such as not being very sensitive to certain types of model errors and being affected by how groups are defined (94). It may detect minor discrepancies in large samples, leading to misleading conclusions about fit (94). It is best complemented with a specification test like the linktest for a more comprehensive evaluation, as conducted.

Confounders

Confounders were assessed to determine their association with the outcome variables. Urban status and smoking status were evaluated but were not controlled for, as their inclusion had a negligible effect on the beta coefficients. Unfortunately, median household income could not be used as a confounder as the variable was removed from the recent wave to maintain anonymity.

Grade level and sex/gender were included as confounding variables where applicable, based on prior research, as these are very common confounders in studies of youth behaviour

(10–12). Additionally, grade serves as a proxy for age, and both age and sex are generally exempt from the rules for confounding. The observed association became stronger after adjusting for sex/gender and grade, indicating that they can be classified as negative confounders. A likelihood ratio test was conducted to determine if including the variables improved the model's fit. The results indicated that these two variables significantly improved the prediction of past 30-day vape use beyond that predicted by policy alone ($\chi^2(1) = 871.40$, $p = 0.0001$).

2.3 RESULTS

Descriptive data

As shown in Table 2.1, raw counts and weighed proportions were reported. The first and third columns present the raw counts, while the second and fourth columns display the weighted proportions for each variable. Gender distribution was nearly equal between males and females, aligning with national demographics (95). In 2021/22, the sample had a higher proportion of students in grades 10–12 compared to grades 7–9, suggesting an older cohort for this survey wave. The weighted proportions reflect nearly equal representation of students across each grade. A higher proportion of students identified as male compared to female, possibly from removing approximately 6% who identified with another gender or chose not to disclose their gender. More than 95% of respondents had never smoked cigarettes in both survey waves. Urban status slightly changed between waves. In 2018/19, 85.4% of youth lived in urban areas while in 2021/22, 88.0% did.

Table 2.1: Sample characteristics for Alberta respondents among 2018/19 and 2021/22 waves

	Pre-Policy			Post-Policy			Total	
	Count (%)		Weighted %	Count (%)		Weighted %	Count (%)	
Total sample	6318	(40.6)	47.7	9260	(59.4)	52.3	15578	(100.0)
Grade level								
7	1065	(16.9)	17.4	1359	(14.7)	16.4	2424	(15.6)
8	943	(14.9)	17.0	1257	(13.6)	16.4	2200	(14.1)
9	1167	(18.5)	17.1	1167	(12.6)	16.6	2334	(15.0)
10	1335	(21.1)	16.6	2209	(23.9)	16.9	3544	(22.8)
11	956	(15.1)	15.7	1833	(19.8)	16.8	2789	(17.9)
12	852	(13.5)	16.3	1435	(15.5)	16.8	2287	(14.7)
Grouped grades								
7-9	3175	(50.3)	51.5	3783	(40.9)	49.4	6958	(44.7)
10-12	3143	(49.8)	48.5	5477	(59.2)	50.6	8620	(55.3)
Sex/gender								
Female/woman/girl	3155	(49.9)	49.0	4149	(47.9)	47.4	7304	(48.7)
Male/man/boy	3163	(50.1)	51.1	4505	(52.1)	52.6	7668	(51.2)
Urban status								
Urban	5292	(83.8)	85.4	8144	(88.0)	88.0	13436	(86.4)
Rural	1026	(16.2)	14.7	1116	(12.0)	12.1	2142	(13.7)
Smoking status								
Current smoker	158	(2.5)	2.6	151	(1.6)	1.7	309	(2.0)
Former smoker	47	(0.7)	0.8	32	(0.4)	0.3	79	(0.5)
Never smoker	6105	(96.8)	96.6	9054	(98.0)	98.0	15547	(97.5)
Vaped in past 30 days								
No	4709	(78.5)	80.1	7477	(83.1)	85.2	12186	(80.4)
Yes	1448	(23.5)	19.9	1523	(16.9)	14.8	2971	(19.6)

Vaping prevalence

When data were collected in 2018/19, 19.9% of youth had vaped in the past 30 days. When data were collected in 2021/22, 14.8% of youth had vaped in the past 30 days, as shown in Table 2.2. This represents a 5.1% decrease in youth vaping over the 27-month period between surveys. After adjusting for grade and sex/gender, there was a 35% decrease in the odds of youth vaping after the policy was implemented.

The role of sex/gender

I stratified the analyses to examine differences in vaping behaviour changes by sex/gender. There were 21.7% of males who vaped in the past 30 days and 17.9% females in 2018/19. It is consistent with recent Canadian literature where males are vaping more than females (12). Notably, this switched in the recent survey wave with 13.0% of males and 16.2% of females having vaped in the past 30 days. There was a 50% decrease in the odds of vaping among males after the Alberta vaping policy was implemented, corresponding to an 8.7% reduction in prevalence. In contrast, females saw only a 1.7% reduction, with their results not reaching statistical significance.

Grade levels

I grouped younger grade levels (7–9) and older grade levels (10–12) together to investigate age-specific variations. Among grades 7–9, vaping prevalence decreased by only 1.2%, a reduction that was not statistically significant. Grades 10–12, however, experienced the largest reduction, with a 9.7% decrease in prevalence. Students in the higher grades had 41% lower odds of vaping after the policy implementation compared to before.

Table 2.2: Odds ratio (OR) and adjusted odds ratio (AOR) of past 30-day vape use before and after policy implementation, stratified by sex/gender and grade

Models	Vaping prevalence (%)	OR (99% CI)	AOR (99% CI)[a]
Model 1: Full Sample (*n* = 15578)			
Unexposed to policy (2018/19)	19.9	Reference	Reference
Exposed to policy (2021/22)	14.8	0.70 (0.31-0.81)	0.65 (0.56-0.76)
Model 2: Females (*n* = 7128)			
Unexposed to policy (2018/19)	17.9	Reference	Reference
Exposed to policy (2021/22)	16.2	0.89 (0.72-1.08)	0.85 (0.69-1.05)
Model 3: Males (*n* = 7444)			
Unexposed to policy (2018/19)	21.7	Reference	Reference
Exposed to policy (2021/22)	13.0	0.54 (0.44-0.66)	0.50 (0.40-0.63)
Model 4: Grades 7-9 (*n* = 6697)			
Unexposed to policy (2018/19)	9.8	Reference	Reference
Exposed to policy (2021/22)	8.6	0.87 (0.71-1.06)	0.83 (0.67-1.02)
Model 5: Grades 10-12 (*n* = 8128)			
Unexposed to policy (2018/19)	30.4	Reference	Reference
Exposed to policy (2021/22)	20.7	0.60 (0.50-0.71)	0.59 (0.49-0.70)

[a]Models were adjusted for sex/gender and grade level where applicable. All estimates are weighted.

2.4 DISCUSSION

This study employed a serial cross-sectional pre-post design using data from the two most recent waves of the Canadian Student Tobacco, Alcohol, and Drugs Survey. Focusing on respondents from Alberta, I examined changes in vaping prevalence before and after the implementation of a new vaping policy in July 2021. There is currently no peer reviewed research which focuses on the impact of this legislative intervention in the province. While the relationship between policy and youth vaping has been studied more heavily in the United States and other countries, there is limited research on its effect within the Canadian context (10,11,73). While the long-term impacts of youth vaping remain uncertain, it is essential to prioritize prevention to mitigate the risk of a potential epidemic of non-communicable diseases.

The main finding in this chapter found a 5.1% reduction in youth vaping after the policy was implemented. Olson and colleagues examined adolescent tobacco use in Minnesota before and after local restrictions were enacted on menthol (2018) and other flavoured (2016) tobacco products (74). They found that cities with policies experienced a smaller increase in adolescent tobacco use compared to the rest of state, indicating that policy change may influence youth behaviours (74). Similarly, Dai et al. found that the T21 policy which raised the minimum purchasing age from 18 to 21 years in the U.S. mitigated the increase in e-cigarette use among youth in both rural and urban areas, though disparities were noted, with a larger increase in rural areas (96).

Caution is needed in attributing the observed changes directly to the policy implemented in Alberta. Youth vaping declined 3.4% across Canada between 2018 and 2021, suggesting that broader trends may have also contributed to the observed reduction (8,9). For example, in 2018/19, 29.6% and 29.9% of youth had vaped in the past 30 days and in 2021/22, 23.7% and 26.6% had recently vaped in Saskatchewan and Newfoundland, respectively. Other provinces that have enacted policy changes that limited youth access to vaping have witnessed reductions in youth vaping. Manitoba enacted a policy in 2017 and documented a 4.8% decrease in the same 27 month timeframe (8,9,97). Ontario implemented a policy in 2018 and documented a 2.5% decrease in this period (8,9,98).

In 2018, the Government of Canada updated the Tobacco Act to the Tobacco and Vaping Products Act to address the growing use of vaping products (99). The federal update aimed to protect youth and non-tobacco users by restricting access, preventing inducements, reducing nicotine dependence, and raising public awareness of the health risks associated with vaping (99). This federal update, combined with Alberta's new provincial vaping legislation, may have worked together to reduce youth vaping rates in the province. Regional differences in policy implementation, cultural norms, and socioeconomic factors could influence vaping behaviours, potentially limiting the applicability of these results.

Greater reduction in male vaping

A second key finding was that the decrease observed among youth vaping was more pronounced among male youth (8.7%) while females experienced an insignificant decrease in use. The reason for this difference is not clear but raises important questions about how vaping behaviour differs among genders. For example, an evaluation of California's T21 policy, revealed greater reductions in lifetime e-cigarette use and lifetime use of any tobacco product among sexual minority youth compared to their non-sexual minority peers (17). Johnson et al. found in 2019 that transgender youth were more likely to use tobacco products than their nonminority peers (18). This highlights the possibility that certain subgroups may experience more pronounced effects from policy interventions.

Female youth reported higher vaping rates in 2021/22 than in 2018/19, contrasting with previous literature, which typically shows males engaging in vaping at higher rates than females (12,13,100). This shift in behaviour among females may reflect broader trends in risky behaviour, as prior research suggests that they may be "catching up" to males in risky behaviours (101). No statistically significant difference in vaping prevalence among females was found, while males experienced a 50% reduction in the odds of past 30-day vape use post policy.

In the international 2024 systematic review on youth vaping policy, sex was identified as a key confounder requiring consideration, either through study design or analytical adjustments (10). Chan et al. accounted for sex as a covariate in their analysis, but they did not evaluate sex- or gender-specific variations in vaping behaviour (73). Similarly, Nguyen's Canadian study on the impact of provincial bans on youth vaping use included sex as a confounder but did not stratify by sex or gender (11). This pattern is consistent across much of the literature, where sex and gender are commonly controlled for rather than examined as effect modifiers (10).

In contrast, Schneider et al. examined reductions in tobacco use after increasing the minimum legal sales age to 21 and found a 6% decline in cigarette use among both males and females (102). Although their study focused on combustible cigarette use rather than vaping, the findings differ from those of this thesis, where the impact of vaping policy varied by sex/gender. By stratifying analyses, this study contributes to the growing body of literature that policy impacts on youth vaping may not be uniform across subgroups. These findings highlight potential gender disparities and emphasizes the importance of considering gender-specific approaches to public health interventions.

Greater reduction in vaping in grades 10–12

The prevalence of vaping among older students remains substantially higher than among younger students; however, I observed a 9.7% reduction in use among grade 10–12 students, compared to an insignificant reduction in grades 7–9. This suggests that grade-specific factors may shape how youth respond to the policy. Research by Knoll et al. highlights this phenomenon, showing that older adolescents aged 13–17 are particularly susceptible to peer influence compared to their younger counterparts aged 10–12 (103). Older teenagers have a better perception of risk and potential consequences of risky behaviour (104). Supporting this theory, recent results from the CSTADS 2023/24 found that grade 12 students were less likely to believe that there was no risk of using vapes with nicotine (14%) compared to grade 7 students (19%) (105). These findings emphasize a critical transitional phase during adolescence, where peer influence and evolving social dynamics may play a significant role in shaping perceptions and behaviours.

Age is widely recognized as a key confounder in youth vaping research. In the 2024 systematic review on youth vaping policy, age was identified as a prespecified confounder requiring adjustment through study design or analytical methods (10). Similarly, Chan et al. treated age as a covariate in their analysis (73). Nguyen's study on provincial bans in Canada included grade as a covariate, while Macinko and Silver also controlled for grade when evaluating New York City's 2014 minimum legal age policy on youth tobacco use (11,106). Across the literature, age or grade is typically controlled for as a confounder rather than used as a variable for stratification. By contrast, my thesis addresses this gap by examining differences in vaping behaviour between younger and older grades. This approach enhances understanding of how youth vaping trends vary by age group, which could have implications for tailoring youth vaping prevention strategies.

Key findings

Overall, there was a 5.1% decrease in vaping prevalence among students in Alberta between 2018/19 and 2021/22. This decline was driven primarily by a statistically significant decline among males and older students (grades 10–12). The change for females and younger students (grades 7–9) were not significant. The sharper decline in older students may suggest greater awareness of consequences, more exposure to health messaging, or behavioural maturity (104). Conversely, the stability of rates among younger students may indicate gaps in education, social factors normalizing vaping, or limited understanding of risks and consequences (104). The limited change among females suggests a need to explore sex and gender-specific influences on vaping behaviours, including social pressures and targeted marketing strategies.

Strengths and Limitations

Strengths of this study include the use of large samples of data collected from students in a natural, school-based setting. The use of pre-calculated survey weights adjusts for non-response and sampling design, improving the generalizability of the findings to the broader student population in Alberta and Canada. Response rates were strong with less than 5% of responses marked “not stated”. By comparing two time points (before and after the policy change), this study offers valuable insights into shifts in vaping behaviour following regulatory interventions.

Another strength of this thesis is its application of implementation science principles. By evaluating a policy within real-world conditions, this approach emphasizes external validity, ensuring the findings are applicable to broader populations. The simultaneous province-wide rollout of the policy reflects natural complexities that are a trademark of implementation research, highlighting how interventions function in dynamic environments.

Limitations include use of cross-sectional data. There were changes in vaping behaviour among youth in the time span examined, making it difficult to determine the extent to which the decrease in vaping prevalence can be attributed to the policy change that took place in Alberta in 2021. Changes in outcomes could be influenced by other factors, such as evolving trends over time. The COVID-19 pandemic shifted some youth from in-person classes to virtual settings, potentially contributing to the observed prevalence shift. Limited access to peers for obtaining products and increased supervision by guardians may have influenced vaping behaviours during this period.

A systematic review by Reiter et al. highlighted that because of the complexity of population-level regulations, all included studies had an elevated risk of bias (10). Evaluating the impact of such policies is challenging because external factors such as cultural norms, shifting product availability, and disruptions from events like COVID-19 can confound results making it difficult to isolate the policy's true reach. This susceptibility can potentially compromise internal validity of this study. While efforts were made to address confounding variables during analysis, ensuring the complete identification and accurate measurement of all variables presents challenges. Not all identified confounders were available or consistent between survey waves, leaving residual confounding a concern. Additionally, public policy issues are often complex, multifaceted, and subject to controversy, with no straightforward solutions (33). As a result, it is important to assess the information available to provide an unbiased assessment for public policymakers (33).

While a response rate of 60% is generally considered acceptable for most research studies, Alberta's rate in 2018/19 was only slightly above this threshold at 62%, potentially introducing some non-response bias (1,25). The specific response rate for the 2021/22 survey is not yet publicly available. However, given that response rates in Alberta for the 2014/15 and 2016/17 cycles were 59% and 75%, respectively, it is reasonable to expect that the 2021/22 response rate will be near or above the acceptable threshold (26,27). Non-response can be attributed to parent/guardian refusals, student refusals, or absenteeism the day of implementation. Underestimation of risky health behaviours may occur due to non-response bias (28). A cross-sectional study of adolescent health revealed that voluntary sampling yielded lower rates of alcohol and tobacco consumption compared to mandatory sampling (28). Youth who did not respond may have had past 30-day vape use thereby reducing the true prevalence.

Another limitation is the lack of representation of truly rural participants with approximately 85% of respondents classified as urban and 15% as rural. Participants in a census metropolitan area and tracked or non-tracked census agglomeration were coded as urban, while the remaining categories were coded as rural (1). However, communities with fewer than 1,000 individuals, which fall under Statistics Canada's definition of rural areas, were likely excluded due to class sizes smaller than 20 students (21). Consequently, the 15% "rural" participants may not be genuinely representative of rural Alberta. Those in rural areas may have different accessibility to products; for example, a village with only one gas station acting as a one-stop shop may contribute to higher prevalence if that facility sells to minors. This is problematic as research has shown higher rates of youth vaping in rural areas than urban, warranting further investigation (96).

2.5 CONCLUSION

I examined vaping prevalence in Alberta before and after a new legislative intervention was implemented to prevent this behaviour among youth. By using data collected from students in a natural setting, this study enhances external validity compared to randomized controlled trials that do not replicate real-world conditions. The findings reveal a 5.1% reduction in youth vaping, with a greater reduction observed among older youth and males, aligning with previous research showing that provincial legislation prohibiting e-cigarette sales to minors may be effective at reducing youth vaping in Canada (11). While it is challenging to definitively conclude whether these reductions are clinically meaningful at this stage, they represent a promising trend that must be monitored.

Youth vaping rates remain still concerningly high, suggesting that additional measures may be necessary to address persistent drivers of use. The cross-sectional design limits the ability to establish causal relationships, however, it offers valuable insights and strengthens the consistency of the association between policy implementation and vaping behaviour. Future research using longitudinal or quasi-experimental methods, such as interrupted time series, could strengthen internal validity and provide more robust evidence of policy impact (32).

CHAPTER 3: CAN POLICY CHANGE REDUCE UNDERAGE VAPE PURCHASES? A SERIAL CROSS-SECTIONAL ANALYSIS OF THE 2018/19 AND 2021/22 CANADIAN STUDENT TOBACCO ALCOHOL AND DRUGS SURVEVY IN ALBERTA.

Contributions of Authors: Chapter 3 has not been submitted for publication to date but may be in the future. I conducted all analyses and drafted the original manuscript. Cheryl Currie, Lars Hallstrom, and James Sanders, and provided valuable feedback, grammar edits, and suggestions to improve the manuscript.

3.1 INTRODUCTION

Background

E-cigarettes were introduced as a tobacco cessation tool for adults in the mid-2000s, yet their use among youth exploded, bringing about immediate and chronic health impacts (3). Nicotine dependence can result from use which can damage the developing brain, and lung injury, pneumonia, respiratory failure, and even death may occur (107–109). Adolescents are particularly susceptible to nicotine addiction as they are vulnerable to social pressures and peer influence (108).

Traumatic injuries such as burns or facial injuries related to vaping device malfunction or modification can also occur (110). These devices typically contain poor quality lithium-ion batteries that when strained, can lead to explosion or fire (53). The 2020 Canadian consumer product safety program found a 73.0% increase in vaping related reports received between 2015 to 2019, reflecting a growing public safety issue (53). By 2020, vaping products were ranked among the top ten reported product types in the program, underscoring the prevalence of vaping-related hazards across Canada (54). For example, in 2021 alone, 52 vaping-related hazard reports were received, with 56.0% involving serious incidents such as poisonings or burns, none of which were fatal (54). These findings highlight the importance of acknowledging not only the internal health risks associated with vaping, but also the physical injuries that can occur if youth use these devices.

Initiation of vaping among Canadian youth often occur at the encouragement of a close friend or acquaintance (56). This behaviour typically takes place during social gatherings, driven by curiosity and a perception that trying vaping was a low-risk activity (56). Youth have acknowledged the fruity flavours, convenience, and discreetness of vaping enable them to continuously vape throughout the day in locations that do not allow combustible cigarettes (61).

Vaping among youth in Canada has increased from 5.7% in 2014/15 to 20.2% in 2018/19 (9,67). Nationally, 21.5% of male youth and 18.9% of female youth reported vaping in 2018/19 (8). However, this trend reversed by 2021/22, with 14.6% of males and 18.6% of females reporting vaping (9). Eastern Canadian provinces tend to have higher youth vaping rates than Western provinces. For example, nearly 27% of youth in Newfoundland were vaping in 2021/22 compared with 16% in British Columbia (9). In recent years, Alberta has fallen below the national average with 14.8% users compared to nearly 16.8% nationally (9).

The perception of the ease with which e-cigarettes can be obtained among underage youth is alarming. Results from the 2018/2019 CSTADS found that over half of Canadian students in grades 7–12 believed that obtaining an e-cigarette would be “fairly easy” or “very easy” (8). A repeat cross-sectional study which analyzed seven waves of an international youth tobacco and vaping survey found that over 65.0% of Canadian youth thought it would be easy to access e-cigarettes (68). In 2018, 24.0% of students under 18 years of age purchased tobacco in Alberta while across Canada 38.0% purchased vape devices from a retailer or online (80). Youth below the legal purchasing age of 18 years are acquiring e-cigarettes in violation of federal law

(77). This public health crisis has triggered legislative updates at both federal and provincial levels.

Vaping products are regulated in Canada, and it is illegal for youth to be purchasing, possessing, and/or using the products. In 2018, the Government of Canada updated the Tobacco Act to the Tobacco and Vaping Products Act (TVPA) to address the growing use of vaping products (99). The TVPA sets federal standards for the production, sale, labelling, and marketing of tobacco and vaping products in Canada (77). While provinces and territories must adhere to the federal legislation, they can also enact their own laws that impose stricter regulations in certain areas. The federal policy does not specify how age verification of those under 18 years old is carried out (77). Provincial or territorial legislation tends to be more stringent regarding access, promotion, and place of use. Research has shown that in provinces with their own legislation prohibiting access and use, youth had a better perception of the harms, and the prevalence increased but at a statistically slower rate than in provinces without a ban (11).

In 2002, the province of Saskatchewan was first in Canada to introduce a policy to prevent tobacco use for their residents (34). This legislation was amended in 2019 to include a restriction on e-cigarette sales to minors (34). The Northwest Territories enacted a vaping policy shortly before Alberta. Their regulation was released in March 2020 and has since been updated in 2022 to further attempt reduction in vaping (35,36). Nunavut, as the most recent territory in Canada to do so, implemented its policy in May 2023 (78).

Alberta Vaping Policy

The Tobacco, Smoking and Vaping Reduction Act (TSVRA) was enacted in Alberta in July 2021 with the aim of safeguarding citizens from the dangers posed by tobacco and vaping products, as well as to tackle the rise in youth vaping (15). The policy establishes the minimum age requirement of 18 years and mandates government-issued photo identification for purchasing, possessing, and consuming vaping products (6). Additionally, it imposes restrictions on advertisements, displays, and promotional materials, as well as limits on the locations where vape products can be sold (6). While the policy includes conditions for youth, such as prohibiting minors from possessing, consuming, or using tobacco or vaping products, the majority of the legislation focuses on regulating the facilities that distribute these products (6).

The new policy prohibits minors from purchasing products at regulated facilities in the province (6). It also excludes youth from entering certain specialty shops that have products on display. The federal legislation does not allow products to be sold to those under 18 years of age to protect the health of adolescents (77). However, before the implementation of Alberta's policy youth were illegally obtaining products with nearly 1 in 5 youth under 18 purchasing tobacco in 2018 (80). Although research concerning the assessment of underage e-cigarette purchasing exists in the United States, similar studies are lacking in Canada (37–40,85). Internationally, a 2024 systematic review investigating the impacts of policy on youth vaping found insufficient evidence to suggest minimum age restrictions, restrictions on location of use, and combined/mixed regulation to reduce youth vaping (10). They did however find that sales licenses, flavour bans, and taxation were generally associated with decreased prevalence of youth vaping (10).

In Canada, one researcher examined the impact of provincial policy on vaping behaviour using provinces without their own legislation as control (11). Nguyen found that youth in provinces with a ban were 29.0% more likely to obtain vaping products from social sources (11). While overall e-cigarette use increased across all examined provinces, the rate of increase was 79.0% lower in provinces with their own legislation (11). Alberta was used as a control in this study, highlighting the importance of investigating the specific impacts of vaping policy implementation within the province.

Objectives

The main objective of Chapter 3 is to examine underage vape and vape product purchases in Alberta using two waves of the CSTADS before and after the new vaping policy was introduced in 2021. I also examined whether male or female youth would be more likely to change purchasing behaviour after the policy was implemented.

3.2 METHODS

Setting & design

This analysis is a serial cross-sectional design (combined sample n = 13,291), which is used to identify changing patterns over time (7). The surveys gather data at multiple points across a longitudinal timeline, with each wave sampling a new cohort from the same population (7). This approach allows for the calculation of prevalence rates based on the collected data.

Alberta youth in grades 7–11 who completed the Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS, n = 5,466) between October 2018 and June 2019 formed the pre-policy sample. The post-policy sample were Alberta youth in grades 7–11 who completed the CSTADS between September 2021 and June 2022 (n = 7,825) (5,9). A stratified single-stage cluster design was used, stratifying by health region and school type (1). Each provincial sampling frame defined two to three health regions, and two categories based on school level. A separate category was defined for larger urban centres, encompassing Edmonton and Calgary in Alberta. Data were collected within schools during a class period. Teachers were in the room and were told not to circulate during the questionnaire to maintain anonymity.

Participants

The target population of the CSTADS consisted of all Canadian residents enrolled in public, private, and Catholic schools in grades 7–12 (1). Students were administered the paper questionnaire if they had parental permission or were of age to consent and were enrolled in an eligible class. Schools with fewer than 20 students enrolled in any eligible grade, virtual schools, schools on a military base, schools on Indigenous land, and schools for special needs, hearing or visually impaired were excluded. Students were given the opportunity to decline participation on the day of the survey. A combination of active and passive permission methods was used, with school boards and schools determining the most appropriate method to obtain parental consent. Participants from outside of Alberta were excluded from my thesis.

Survey weights

In complex survey designs like CSTADS, the sample data are multiplied by specific weights that account for varying sampling fractions to generate a representative estimate for the survey population. Without the use of survey weights, one simply derives estimates based on the individuals included in the sample, n, rather than a population estimate of N (1,2). A critical purpose of survey weights is to correct for sampling methods and overall survey nonresponse (2). Ideally, if every person in a population had an equal chance of being selected and participated in the survey equally, all cases would have the same survey weight, reflecting the inverse probability of selection and response. However, due to the more complex sampling methods used in CSTADS and the uneven nonresponse rates, not all individuals had an equal chance of participating. Both the 2018/19 and 2021/22 surveys included pre-calculated survey weights, determined by researchers at Health Canada (1,2). Raw counts were analyzed without applying weights, while all regression models and proportion estimates were generated using survey weights.

Variables

Outcome: underage vape purchase

The main outcome in this chapter is underage purchases at retail stores. Students were asked about how they obtain their vaping products and self-reported purchase of vape products from a retail store (i.e. convenience store or vape shop). In 2018/19 surveyors asked a single question about source of vape devices and e-liquids, while in 2021/22 this was split in two to capture more details as seen in Appendix 3.

To measure vape purchases, I created a dichotomous variable indicating self-reported retail store purchases. Options "I buy them from a vape shop” and "I buy them from a convenience store" were coded as 1, while all other options were coded as 0, excluding those who do not vape and those who did not answer. This decision was made as the policy explicitly prohibits the sale of vapes to minors, meaning that individuals under the age of 18 should not have access to products at these retail stores.

Both vape shops and convenience stores are acknowledged as tobacco/smoking/vaping retailers by Public Health Inspectors and Tobacco/Smoking/Vaping Investigators who are partially responsible for inspecting these establishments (15). Other response options for this question, such as online purchases, are not subject to the policy's regulations. Regrettably, Health Canada removed the age variable to safeguard the confidentiality of participants (1). Grade levels served as a proxy for age, as 95.0% of youth fall within the expected age range for their respective grade (i.e., grade 7: 12-13, grade 8: 13-14, grade 9: 14-15, grade 10: 15-16, grade 11: 16-17, and grade 12: 17-18) as confirmed with a Health Canada analyst. Individuals in grade 12 were excluded from the analysis (~16% of the weighed sample) as they may be over the legal age of 18 to purchase vaping products in Alberta.

Exposure: vaping policy change

The exposure in this study is the introduction of the Tobacco, Smoking and Vaping Reduction Act in Alberta in July 2021. I compared a survey on past 30-day vaping among Alberta youth in 2018/19 to a similar survey conducted beginning in the fall of 2021. This survey was conducted after the new vaping policy was enacted in the province. A binary variable was created where respondents from 2018/19 were coded as 0 (pre-policy) and respondents from 2021/22 were coded as 1 (post-policy).

Confounders

Variables selected for consideration as confounders include sex/gender, median household income (as an indicator of socioeconomic status [SES]), smoking status, and urban status. These variables were selected based on their potential to influence the observed association. Participants self-reported their grade level and gender. Median household income was ascertained using the school's postal code (1). Specifically, the first three digits of the postal code were matched with the 2016 Canadian Census data on median household income, subsequently rounded to the nearest $5000. Smoking status was a derived variable with 3 levels: current smoker, former smoker, or never smoker (1).

Health Canada collected data on both sex at birth and gender identity. In 2018/19, the sex at birth variable was provided in the public dataset while in 2021/22 they removed sex at birth and provided gender. This made it difficult to compare between survey waves. Ultimately, I removed 6.5% of respondents in the recent survey who selected "another gender or gender not stated" from the recent wave to make it comparable and is why I am referring to the variable as sex/gender. Without detailed data, one cannot consider focused strategies to address the specific needs of LGBTQ+ individuals, who face additional health inequities and systemic discrimination. While sex/gender was considered a confounder due to its association with youth vaping behaviour, it was ultimately included as a stratification variable.

To derive the urban variable, the school's postal code was matched to its Statistics Canada Census Dissemination Area. Participants located within 20 kilometres of Calgary or Edmonton were coded as urban while the remaining categories were coded as rural (1). Statistics Canada states that rural areas are villages or small towns with less than 1,000 population (21). The survey design does not align with this definition, as communities with fewer than 1,000 individuals likely have class sizes smaller than 20 students and were therefore excluded.

Bias

To mitigate potential selection bias, the survey designers implemented key considerations. Schools with fewer than 20 students enrolled in any eligible grade were excluded from the sampling frame (1). Sample selection was based on school participation rates of elementary and secondary schools using data from previous cycles of the survey, ensuring a minimum sample size to yield generalizable results. Once the list of sampled schools for each province was generated, the co-investigator overseeing implementation in that province reviewed the overall distribution of schools to identify potential concerns at the provincial level. Teams within each province were tasked with recruiting school boards. Randomly chosen schools were approached for participation. To maintain consistency and monitor progress across Canada, permitted staff utilized an online, real-time database.

Misclassification, a type of measurement error, can occur if a variable is missing or assigned to the wrong category (7). To minimize misclassification of the grade variable, data analysts examined instances where the reported grade was inconsistent with the student's school or where a response was missing. In such cases, the response was recoded to the median grade of the class to which the student belonged (1).

Sample size

Sample size considerations occurred during the design stage to assist with generalizability (1). The stratified single-stage cluster design ensured sufficient sample sizes within the strata's and increased precision (1). In 2018/19, 107 students (1.7%) did not answer the question on vape source. In 2021/22, 169 and 327 students (1.8%, 3.5%) did not answer the survey questions on source of vape devices, and e-liquids or pods, respectively. Missing data were removed using listwise deletion, as the amount of missing data were negligible (<5%), ensuring that the remaining sample size was sufficiently large to provide reliable estimates. The final sample sizes for Alberta were 5,466 for the 2018/19 survey and 7,825 for the 2021/22 survey.

Statistical methods

Sample characteristics were examined using unweighted counts and proportions. Weighed odds ratios and 99% confidence intervals were used to assess changes in underage vape purchases before and after the policy change. Logistic regression is widely used in epidemiological research, where outcomes often have only two possible values, such as the presence or absence of a behaviour, or whether a particular event occurred during a specified time frame (94). It helps model the probability of these binary outcomes based on one or more predictor variables.

A total of six models were run: one unadjusted model to predict the odds of underage vape purchase, one adjusted model accounting for sex/gender, and four stratified models (unadjusted and adjusted) for females and males. This approach allowed for both unadjusted and adjusted assessments the change vape purchasing patterns across different subgroups. All analyses were performed using STATA/SE 18.0. Log files documenting the creation of Table 3.1 and 3.2 are available upon request.

Normality

To test if the models have a normal distribution of errors, the linktest was run. The hat was not statistically significant, demonstrating a lack of model fit. Hatsq was omitted because of collinearity. Additionally, the Hosmer-Lemeshow test yielded a significant result, further suggesting poor fit. It is important to note that this test has several limitations, such as not being very sensitive to certain types of model errors and being affected by how groups are defined (94). It may detect minor discrepancies in large samples, leading to misleading conclusions about fit (94). Despite these initial findings, once confounders were included in the analysis, the linktest showed that _hat became statistically significant while _hatsq was not, indicating appropriate model specification. Furthermore, the Hosmer-Lemeshow test result was no longer significant, suggesting a good fit for the adjusted logistic regression model.

Confounders

Confounders were assessed to determine their association with the outcome variables. Urban status and smoking status were evaluated but were not controlled for, as their inclusion had a negligible effect on the beta coefficients. Unfortunately, median household income could not be used as a confounder as the variable was removed from the recent wave to maintain anonymity.

Grade level and sex/gender were included as confounding variables where applicable, based on prior research, as these are very common confounders in studies of youth behaviour

(10–12). Additionally, grade serves as a proxy for age, and both age and sex are generally exempt from the rules for confounding. The observed association became stronger after adjusting for sex/gender and grade, indicating that they can be classified as negative confounders. A likelihood ratio test was conducted to determine if including the variables improved the model's fit. The results indicated that these two variables significantly improved the prediction of underage vape purchases beyond that predicted by policy alone ($\chi^2(1) = 138.89$, $p = 0.0001$).

3.3 RESULTS

Descriptive data

As shown in Table 3.1, raw counts and weighed proportions were reported. The first and third columns present the raw counts, while the second and fourth columns display the weighted proportions for each variable. The weighted proportions reflect nearly equal representation of students across each grade. Gender distribution was nearly equal between males and females, aligning with national demographics (95).

The weighted proportions reflect almost equal representation of students across each grade. A higher proportion of students identified as male compared to female, possibly from removing approximately 6.0% who identified with another gender or chose not to disclose their gender. More than 95.0% of respondents had never smoked cigarettes in both survey waves. Urban status slightly changed between waves. In 2018/19, 85.7% of youth lived in urban areas while in 2021/22 87.5% did. The remaining youth identified as living in "rural" areas may not realistically be representative of rural communities in Alberta.

Table 3.1: Sample characteristics for partial Alberta respondents among 2018/19 and 2021/22 waves

	Pre-Policy		Post-Policy		Total
	Count (%)	Weighted %	Count (%)	Weighted %	Count (%)
Total sample	5466 (41.1)	47.9	7825 (58.9)	52.1	13291 (100.0)
Grade level					
7	1065 (19.5)	20.8	1359 (17.4)	19.7	2424 (18.2)
8	943 (17.3)	20.4	1257 (16.1)	19.7	2200 (16.6)
9	1167 (21.4)	20.4	1167 (14.9)	20.0	2334 (17.6)
10	1335 (24.4)	19.8	2209 (28.2)	20.3	3544 (26.7)
11	956 (17.5)	18.7	1833 (23.4)	20.2	2789 (21.0)
Sex/gender					
Female/woman/girl	2726 (49.9)	49.0	3499 (47.8)	47.3	6225 (48.2)
Male/man/boy	2740 (50.1)	51.0	3815 (52.2)	52.7	6555 (51.9)
Urban status					
Urban	4576 (83.7)	85.7	6816 (87.1)	87.5	11392 (85.7)
Rural	890 (16.3)	14.4	1009 (12.9)	12.5	1899 (14.3)
Smoking status					
Current smoker	107 (2.0)	1.7	106 (1.4)	1.3	213 (1.6)
Former smoker	31 (0.6)	0.5	24 (0.3)	0.3	55 (0.4)
Never smoker	5321 (97.5)	97.8	7676 (98.3)	98.4	12998 (98.0)
Purchased products at convenience store or vape shop					
No	1263 (85.5)	87.4	1117 (86.3)	86.7	2380 (85.9)
Yes	214 (14.5)	12.6	178 (13.8)	13.3	392 (14.1)

Underage vape purchases

When data were collected in 2018/19, 12.6% of youth in grades 7–11 self-reported purchasing vape products at a convenience store or vape shop (Table 3.2). When data were collected in 2021/22, 13.3% of youth had reported purchasing vape products at a convenience store or vape shop. This represents a 0.7% increase in self-reported underage purchases over the 27-month period between surveys, although this change was not statistically significant (OR: 1.07, 99% CI: 0.72-1.57).

The role of sex/gender

I stratified the analysis to investigate possible sex/gender differences in underage vape purchasing patterns. Females had a 2.2% self-reported reduction in vape purchases, while male purchases increased by 2.4%, however, none of these findings were statistically significant.

Table 3.2: Odds ratio (OR) and adjusted odds ratio (AOR) of underage vape purchases before and after policy implementation, stratified by sex/gender

Models	Prevalence (%)	OR (99% CI)	AOR (99% CI)[a]
Model 1: Full Sample (*n* = 2674)			
Unexposed to policy (2018/19)	12.6	Reference	Reference
Exposed to policy (2021/22)	13.3	1.06 (0.80-1.41)	1.07 (0.72-1.57)
Model 2: Females (*n* = 1413)			
Unexposed to policy (2018/19)	12.1	Reference	Reference
Exposed to policy (2021/22)	9.9	0.83 (0.46-1.47)	0.82 (0.45-1.47)
Model 3: Males (*n* = 1261)			
Unexposed to policy (2018/19)	16.8	Reference	Reference
Exposed to policy (2021/22)	19.2	1.37 (0.85-2.21)	1.30 (0.79-2.12)

[a] Models were adjusted for grade level, and sex/gender where applicable. All estimates are weighted.

3.4 DISUCSSION

The purpose of Chapter 3 was to examine self-reported vape purchases among students in grades 7–11 who would be under 18 years of age before and after the policy was implemented in

July 2021. The findings revealed that, while there was a slight increase in the proportion of youth who reported purchasing vape products underage, these changes were not statistically significant. This may suggest that the policy did not have a measurable effect on reducing underage vape purchases during the study period among students in grades 7–11. However, it is important to recall that vape use did not change during period among students in grades 7-9 and youth in grades 10-12 saw a nearly 10% decline as was reported in the previous thesis chapter.

Some research exists on youth vape purchasing behaviours before and after implementation of policy change. Like this study, a US population-based cohort study found no statistically significant change in underage vape shop purchases pre- and post-policy to restrict this behaviour (87). The majority of those under 21 reported that e-cigarettes were harder to buy compared with the year prior (87). Kong and colleagues examined sources of e-cigarettes among youth in Connecticut after a law restricting the sale of e-cigarettes to minors was introduced and found no changes in the prevalence of youth who reported obtaining products from a commercial source (39). Nguyen examined provincial bans on e-cigarette sales to minors in Canada and found that such policies were only partially effective (11). Youth in provinces with bans were less likely to purchase e-cigarettes from grocery stores, convenience stores, and vape shops compared to those in provinces without bans (11). Nevertheless, increased use of social sources for obtaining e-cigarettes was observed in provinces with bans (11).

A cross-sectional study examined tobacco purchasing patterns before and after the minimum legal purchasing age increased from 18 to 21 years old in the US (86). This research found that while the percentage of youth reporting easy access to tobacco products declined after the policy, most underage purchase attempts remaining successful (86). A longitudinal cohort study examined age verification for vape and cigarette purchases before and after the staggered implementation of a policy in the United States that raised the minimum legal purchasing age from 18 to 21, referred to as T21 (111). The findings revealed that states with the T21 law had a higher likelihood of verifying the age of those purchasing vape products, but this was not the case for cigarette purchases (111). Over time, age verification for vape products increased in all states, regardless of whether they had implemented T21 or not (111).

Braak et al. researched vape sources among 3 high income countries (Canada, US, England) and found that among those who vaped in the past year, 11.3% reported being refused the sale of vaping products because of their age (83). For those under the minimum legal purchasing age, 68.7% reported refusal of sale (83). They also noted that purchasing of products was related to being of legal age for purchasing the vaping products (83). The data collected in this type of research relies on self-reporting. Self-reported data can be prone to reliability issues, particularly when respondents are asked to disclose behaviours they know are prohibited (28). This limitation likely contributes to underreporting and should be considered when interpreting the findings.

In relation to these studies, Chapter 3 found that vape purchases among grades 7–11 students (that would be under 18 years of age) essentially did not change in the year after a policy was introduced to restrict this behaviour. Regulatory variations and enforcement gaps could limit the effectiveness of minimum legal sales age policies, emphasizing the need for stronger compliance monitoring and enforcement mechanisms.

Sex and gender analysis

Braak and colleagues reported that among Canadian adolescents who had vaped in the past 12 months, males had 76% higher odds of purchasing products compared to females (83). Similar patterns were observed in the United States and England, where being male was associated with 75% and 35% higher odds of purchasing, respectively (83). In this thesis chapter, females reduced their purchasing by 2.3%, while males increased theirs by 2.4%; however, neither change was statistically significant. These results prompt questions about the role of sex and gender differences in influencing youth sources of vaping products, potentially reflecting differing access to resources, social norms, or peer influences between sex and gender.

By stratifying analyses, this study contributes to the growing body of literature suggesting that policy impacts on youth vape source may not be uniform across subgroups (83). The only study specifically examining provincial bans in Canada and their impact on e-cigarette sales to minors did not stratify its analysis by sex or gender, however, sex was included as a covariate in the analysis (11). Future research should explore sex and gender-based differences in youth vaping sources across Canadian provinces to provide a more nuanced understanding of these dynamics.

Strengths and Limitations

Strengths of this study include the use of large samples of data collected from students in a natural, school-based setting. The use of pre-calculated survey weights adjusts for non-response and sampling design, improving the generalizability of the findings to the broader student population in Alberta and beyond. Response rates were strong with less than 5% of responses marked “not stated”. By comparing two time points (before and after the policy change), this study offers important insight into vape purchasing patterns following regulatory interventions.

Another strength of this thesis is its application of implementation science principles. By evaluating a policy within real-world conditions, this approach emphasizes external validity, ensuring the findings are applicable to broader populations. The simultaneous province-wide rollout of the policy reflects natural complexities that are a trademark of implementation research, highlighting how interventions function in dynamic environments.

This study was not without limitations. An important limitation was the use of self-reported prevalence data, particularly since youth were reporting engaging in an illegal activity. While teachers were instructed to emphasize the anonymity of the survey, students may still have been hesitant to respond truthfully, leading to potential underreporting. However, comparing self-reported data across two time periods strengthens the findings by reducing this limitation, as it is unlikely that underreporting would differ significantly between the two survey waves.

A systematic review by Reiter et al. highlighted that because of the complexity of population-level regulations, all included studies had an elevated risk of bias (10). Evaluating the impact of such policies is challenging because external factors such as cultural norms, shifting product availability, and disruptions from events like COVID-19 can confound results making it difficult to isolate the policy's true impact. This susceptibility can potentially compromise internal validity of this study. While efforts were made to address confounding variables during analysis, ensuring the complete identification and accurate measurement of all variables presents challenges. Not all identified confounders were available or consistent between survey waves, leaving residual confounding a concern. Additionally, public policy issues are often complex, multifaceted, and subject to controversy, with no straightforward solutions (33). As a result, it is important to assess the information available to provide an unbiased assessment for public policymakers (33).

Grade level was used as an approximate indicator of age, excluding grade 12 respondents because most fall within the age range of 17–18 years old, with 18 being the legal age for purchasing the products. This exclusion was to reduce the likelihood of including those legally permitted to purchase, though it also removed 17-year-old grade 12 students who may have been illegally obtaining products. Given that older adolescents are more likely to purchase and use e-cigarettes compared to younger adolescents, and that otherwise eligible adolescents were removed from the sample, these results are an underrepresentation of the true prevalence of underage purchases.

While a response rate of 60% is generally considered acceptable for most research studies, Alberta's rate in 2018/19 was only slightly above this threshold at 62%, potentially introducing some non-response bias (1,25). Specific response rates for the 2021/22 survey are not yet publicly available. However, given that response rates in Alberta for the 2014/15 and 2016/17 cycles were 59% and 75%, respectively, it is reasonable to expect that the 2021/22 response rate will be near or above the acceptable threshold (26,27). Non-response can be attributed to parent/guardian refusals, student refusals, or absenteeism the day of implementation. Underestimation of risky health behaviours may occur due to non-response bias (28). A cross-sectional study of adolescent health revealed that voluntary sampling yielded lower rates of alcohol and tobacco consumption compared to mandatory sampling (28). Youth who did not respond may have purchased products underage, thereby reducing the true prevalence.

Another limitation is the lack of representation of truly rural participants with approximately 85% of respondents classified as urban and only 15% as rural. Communities with fewer than 1,000 individuals, which fall under Statistics Canada’s definition of rural areas, were likely excluded due to class sizes smaller than 20 students (21). Consequently, the 15% “rural” participants may not be genuinely representative of rural Alberta. Those in rural areas may have different accessibility to products; for example, a village with only one gas station acting as a one-stop shop may contribute to higher prevalence if that facility sells to minors. This is problematic as research has shown higher rates of youth vaping in rural areas than urban, warranting further investigation (96).

It is important to acknowledge that the changes in outcomes could be influenced by other factors, such as evolving trends over time. Due to relying on self-reported data from youth about their vape source, questions remain regarding what is happening at the retail level. I did not have data on the compliance of retail establishments. For those who reported purchasing vaping products from vape shops or convenience stores, there is a lack of information on whether they used fake or borrowed identification, if the employee failed to check their ID, or if a personal relationship with the employee played a role.

3.5 CONCLUSION

I examined if new legislation to prevent youth from purchasing vaping products illegally in Alberta decreased the prevalence of underage purchases among a representative school population. By using data collected from students in a natural setting, this study enhances external validity compared to randomized controlled trials that do not replicate real-world conditions. Vape purchases among grades 7–11 slightly increased overall, although none of the findings in this chapter were statistically significant.

These results build on prior research by testing for potential gender disparities in substance use behaviours, emphasizing the importance of considering sex and gender-specific approaches to both policy design and enforcement to address unique patterns in vaping sources and use (83). Future research in Alberta should focus on assessing age verification practices at the retail level to identify compliance rates and enforcement gaps, especially given the concerningly high rates of underage purchases observed. By evaluating these factors, Alberta and other provinces can develop targeted strategies to strengthen policy implementation.

CHAPTER 4: CONCLUSION

Vaping rates among Canadian youth have risen significantly throughout the 2010s. By 2018/19, nearly 1 in 3 students in grades 10-12 and 1 in 10 students in grades 7-9 had used e-cigarettes in the past 30 days (9). These devices often contain nicotine, which pose significant risks to youth. Nicotine exposure during adolescence can lead to dependence and potentially harm the developing brain (48,49). Youth are also vulnerable to other health impacts, including lung injury, pneumonia, and acute bronchiolitis (50). Additionally, Canadian paediatricians have reported cases of nicotine poisoning and physical injuries, such as burns, associated with the use of these devices (52). Based on a 2017 cross-sectional survey, Braak et al. found that underage youth in Canada who reported purchasing vaping products most cited vape shops (58.1%) and retail stores (30.1%) as their primary sources (33).

In response, federal and provincial governments introduced various legislative measures to mitigate the associated risks. Saskatchewan enacted Canada's first tobacco-related legislation in 2002, which was amended in 2019 to include e-cigarette and vaping-related restrictions (34). Similarly, the Government of the Northwest Territories introduced a vaping policy in March 2020, further strengthening it in March 2022 (35,36).

Nguyen examined provincial e-cigarette bans on youth vaping behaviour in 2020 (11). To my knowledge, this is the only peer-reviewed study examining vaping legislation across Canadian provinces. This study employed quasi-experimental differences-in-differences and triple differences methods to compare changes in vaping outcomes between provinces with their own legislation and those without (i.e. Alberta) (11). Nguyen found that provinces with legislation restricting access and use of e-cigarettes resulted in youth having a better understanding of the associated harms, with vaping prevalence increasing at a slower rate compared to provinces without such bans (11).

In 2021, Alberta enacted the TSVRA, a policy aimed at mitigating the risks associated with tobacco and vaping products while addressing the alarming increase in youth vaping (15). No research to date has examined the potential impact of this legislation on youth vaping behaviours. Given the expectation for public health policymakers to make evidence-based decisions on critical health interventions, it was essential to address the existing literature gap regarding vaping policy in Alberta (32).

This thesis addressed the following five objectives through two research papers:

Paper 1: The first paper explored changes in youth vaping prevalence in Alberta before and after the implementation of the Tobacco, Smoking, and Vaping Reduction Act (TSVRA) in 2021 (objective 1). Additionally, it assessed the influence of sex, gender, and grade level on vaping prevalence (objectives 2 and 3).

Paper 2: The second paper examined the prevalence of underage vape purchases at retail stores before and after policy implementation (objective 4). It also investigated whether sex and gender differences were associated with underage purchasing behaviour (objective 5).

Data were obtained from the 2018/19 and 2021/22 waves of the Canadian Student Tobacco Alcohol and Drugs Survey (pooled n = 15,578). The target population of the survey consisted of all Canadian residents enrolled in public, private, and Catholic schools in grades 7–12, with respondents from outside Alberta removed for this thesis (1). These public datasets allowed for serial cross-sectional analyses of unadjusted, adjusted, and stratified research questions.

Key categorical variables, including vaping prevalence, vape purchases, grade levels, sex/gender, smoking status, and urban status, were summarized as counts and weighted proportions. Logistic regression was used to evaluate the odds of vaping prevalence and underage vape purchases following policy implementation. Both survey waves included pre-calculated weights, developed by researchers at Health Canada (1,2). While raw counts were analyzed without weights, survey weights were applied to all regression models and proportion estimates to ensure representative findings for the survey population. In Chapter 2, I hypothesized that youth vaping prevalence in Alberta would decline following the implementation of the TSVRA. Similarly, in Chapter 3, I anticipated a decrease in the prevalence of underage vape product purchases after the enactment of the TSVRA.

4.1 KEY FINDINGS

The primary aim of **Chapter 2** was to assess change in the prevalence of youth vaping before and after the implementation of a new legislative intervention in July 2021. The main outcome was the prevalence of past 30-day vape use among Alberta youth in grades 7–12. Additionally, this chapter investigated whether change in vaping behaviour differed by sex/gender and grade level. In 2018/19, 19.9% of youth reported vaping in the past 30 days. By 2021/22, this proportion had decreased to 14.8%, representing a statistically significant 5.1% decline over the 27-month period between surveys. After adjusting for grade and sex/gender, the odds of youth vaping decreased by 35% following the policy implementation. While much of the research on the relationship between policy and youth vaping has focused on the United States and other countries, there is limited exploration of this issue within the Canadian context (10,11,73). My thesis contributes to the growing body of literature by providing evidence that policy interventions may reduce youth vaping prevalence.

Objectives 2 and 3 from Chapter 2 highlight important differences in vaping behaviour changes by sex/gender and grade level. In 2018/19, males were more likely to vape than females, but this trend reversed in 2021/22, with 16.2% of females and 13.0% of males reporting past 30-day vaping. While males experienced a 50% reduction in the odds of vaping following the policy (an 8.7% decrease in prevalence), the reduction among females was minimal (1.7%) and not statistically significant.

The reasons for these differences raise important questions about how vaping behaviours vary by sex and gender. Differences in social influences, stress responses, or perceptions of risk may contribute to this disparity, particularly as previous research has shown that substance use patterns often differ by gender or sexual orientation (17,112). An evaluation of California's T21 law, have shown greater reductions in tobacco product use among sexual minority youth, compared to their nonminority peers (17). A longitudinal study focusing on lesbian, gay, bisexual, and transgender (LGBT) youth in Chicago found that while males had higher initial cigarette smoking rates, females' rates increased more rapidly over time, with psychological distress and victimization influencing smoking behaviours, emphasizing the multifaceted social and emotional factors associated with substance use patterns (113).

Research in Chicago has found that substance use patterns differ by gender. Males generally having higher rates of substance use (alcohol, marijuana, and other drugs), while females may experience stronger links between substance use and other risky behaviours like delinquency (112). In hypothetical terms, research suggests that gender differences may be connected to developmental timing in adolescence, with female youth more likely to display stable patterns of delinquency and substance use from age 12 to 15, while males show similar stability from age 15 to 18 (112). Additionally, it has been suggested that boys may face increased risk for disruptive substance use of alcohol due to a combination of factors, including a lower response to alcohol, delayed brain maturation, higher perceived peer use, and expectation into traditional gender roles (114). Although combustible cigarettes and alcohol are not vaping products, they are still substances, making this literature valuable for understanding and investigating youth vaping behaviours.

Chan et al. accounted for sex as a covariate in their analysis, but they did not evaluate sex- or gender-specific variations in vaping behaviour (73). Similarly, Nguyen's Canadian study on the impact of provincial bans on youth vaping use included sex as a confounder but did not stratify by sex or gender (11). This pattern is consistent across much of the literature, where sex and gender are commonly controlled for rather than examined as effect modifiers (10). Results from Chapter 2 suggest that policy interventions may affect different subgroups in unique ways, highlighting the need for further investigation to better understand sex- and gender-based disparities in vaping behaviour.

Older students (grades 10–12) experienced a 9.7% reduction in vaping prevalence, with 41% lower odds of vaping after the policy, whereas no significant changes were observed among younger students (grades 7–9). This suggests that grade or age specific factors may influence how youth respond to such policy interventions. Research by O'Brien and Bierman indicates that adolescents aged 13–17 are particularly susceptible to peer influence compared to their younger counterparts aged 10–12, highlighting a critical transitional phase during adolescence (115). They found that older adolescents had a desire to feel needed or wanted, while younger adolescents are more focused on simply gaining friendships (115). Older teenagers have a better perception of risk and potential consequences of risky behaviour (104). Supporting this theory, recent results from the CSTADS 2023/24 found that grade 12 students were less likely to believe that there was no risk of using vapes with nicotine (14%) compared to grade 7 students (19%) (105). During this period, changing priorities, social dynamics, and peer influence may shape perceptions and behaviours, potentially explaining the more pronounced reductions observed in older students.

This increased susceptibility aligns with the concept of peer contagion, which refers to the process by which behaviours or emotions are mutually influenced between peers, often leading to actions that can be harmful or reinforce negative behaviours (116). Early substance use can provide an entry point into a social environment where use is accepted and reassured by peers, supporting high levels of use (116). For example, research has found that females demonstrated higher levels of substance use in early adolescence, whereas males showed greater changes over time, with higher levels of substance use in mid-adolescence and early adulthood (117). Isakson and Jarvis through a longitudinal study found that during the transition from junior to senior high school (grades 8 to 9) in Illinois, both stressors and social supports increased among youth, intensifying the potential for peer contagion to influence behaviour (118).

Across the literature, age or grade is typically controlled for as a confounder rather than used as a variable for stratification (11,60,106). By contrast, my thesis addresses this gap by examining differences in vaping behaviour between younger and older grades. This approach enhances understanding of how policy impacts may vary by age group, which could have implications for tailoring youth vaping prevention strategies.

Chapter 3 examined vape purchasing prevalence before and after the implementation of Alberta’s new policy among students in grade 7–11 who would be under 18 years of age. The outcome for this chapter was self-reported underage purchases at retail stores (i.e. convenience stores and vape shops) which are subject to the new policy. In 2018/19, 12.6% of underage youth reported purchasing vape products from convenience stores or vape shops, which increased slightly to 13.3% in 2021/22—an insignificant 0.7% increase over the 27-month period. Stratified analyses revealed that females experienced a 2.2% reduction in purchases, while males saw a 2.4% increase in purchases following the policy. However, none of the findings in this chapter reached statistical significance.

While the proportion of underage youth purchasing vape products from commercial sources remained largely unchanged after the policy, similar trends have been observed elsewhere. For example, studies in Southern California and Connecticut reported no significant decreases in underage purchases following the implementation of restrictions (39,87). Nguyen's analysis of Canadian provincial bans found partial success, with reduced purchases from commercial sources offset by increased reliance on social sources (11). A social source typically refers to obtaining vaping products through informal routes, such as having someone purchase them on their behalf, being offered them by peers, or acquiring them without direct purchase from a retailer (83,84). These results highlight possible enforcement challenges that may reduce the intended impact of such policies. The importance of strengthening compliance monitoring and enforcement mechanisms to improve the effectiveness of youth-focused vaping restrictions is clear. Additionally, attention must be given to the social market, as peer influence and social norms play a considerable role in shaping youth behaviour.

Social media use on platforms such as Instagram and TikTok has skyrocketed, with influencers playing a significant role in shaping young people’s lives (119). Youth spend a large part of their time online, and because they relate personally with the influencer, these figures provide information, comfort, and advice (119). When influencers are endorsing these products they can transform youth behaviours, leading to an uptake in use and increase in purchasing (119). While this factor could not be tested for in my thesis, it should be considered as a broader cyclical trend.

School size may also influence vaping practices among youth. While the CSTADS excluded very small schools with less than 20 students in a class, variations in school size would exist. Larger schools within a school division may have stronger internal policies and educational programs to target vaping behaviour, benefitting from greater staff and resources. Milicic et al. found that the odds of being a current vape user were 32% lower in Ontario schools with policies banning e-cigarettes on school property than schools without (120). Their findings suggest that school-level policies may be effective in influencing e-cigarette use among youth (120). However, I was unable to analyze data at the school level in my thesis.

4.2 IMPLICATIONS FOR POLICY AND PRACTICE

The findings from **Chapter 2** emphasize the potential for targeted policies to reduce youth vaping prevalence. In 2018, the Government of Canada updated the Tobacco Act to the Tobacco and Vaping Products Act to address the growing use of vaping products (99). The federal update aimed to protect youth and non-tobacco users by restricting access, preventing inducements, reducing nicotine dependence, and raising public awareness of the health risks associated with vaping (99). Alberta's vaping legislation, implemented alongside the federal Tobacco and Vaping Products Act, may have contributed to a measurable decrease in youth vaping rates.

Regional differences in policy implementation, cultural norms, and socioeconomic factors may shape vaping behaviours and warrant consideration in future policy development and evaluation. For example, Indigenous peoples in Canada face systemic racism, marginalization, and severe health inequities, yet schools on reserves were excluded for surveillance in these surveys (121). It is well documented that the prevalence of varying substance use is significantly higher in this population compared to their non-Indigenous counterparts. One study found that Indigenous youth had five times higher odds of being a cigarette smoker than non-Indigenous youth (122). The harmful impacts of colonialism and lifestyle disruptions significantly affect the social determinants of health, resulting in devastating losses of language, land, and socio-cultural resources (121). The higher prevalence of substance uses among Indigenous youth highlight the need for additional support and tailored interventions.

As seen in other jurisdictions such as the United States, determining the appropriate level of government to implement e-cigarette regulations is not a simple decision (90). State or provincial governments offer the advantage of tailoring policies to meet local needs, acting as regulators that can adapt to emerging challenges and address gaps where national regulations may be absent or delayed (90). They can also serve as testing grounds for innovative strategies, generating valuable evidence to inform broader, national-level initiatives, such as state T21 laws in the United States (90). The reliance on state or provincial approaches carries risks, such as leaving youth in some areas less protected due to policy inconsistencies (90). National policies, while slower to implement, can establish uniform standards, reducing disparities (90). Canada has an opportunity to balance these approaches by leveraging the strengths of both provincial and federal governance.

While the growing public health concerns over e-cigarette use among youth are valid, it is important to acknowledge that prohibitionist measures could inadvertently harm public health by restricting harm reduction options for adult smokers (123). The UK provides a model for a balanced approach to e-cigarette regulation, ensuring safe access for those who smoke while protecting youth through strong measures (123). Their method, rooted in a pre-history of nicotine use for smoking cessation, reflects a harm-reduction approach focused on benefiting existing smokers (124). England's highly centralized governance structure also facilitated a uniform national policy toward e-cigarettes, unlike the federal systems of Canada, Australia, and the United States, where policymaking is divided between federal and provincial/state governments (124). In contrast, the United States and Australia have emphasized the protection of youth and adolescents, often adopting more restrictive policies (124). These variations highlight how national contexts, historical factors, and differing values shape regulatory responses (124). Alberta’s approach could benefit from carefully balancing these perspectives to manage both public health concerns and harm-reduction strategies for smokers (123).

The findings from **Chapter 3** revealed that vape purchasing patterns did not significantly change after implementation of the policy aimed at restricting youth access to these products. Youth should not have access to these products, however, my findings aligns with research from the United States, where raising the minimum legal purchasing age to 21 (T21) did not entirely eliminate underage tobacco purchases, though youth reporting easy access declined (86). Romm et al. found that T21 policies were associated with increased age verification for e-cigarette purchases but had no significant impact on verification for traditional cigarettes, with age verification rates improving over time regardless of T21 laws (111). Similarly, post-policy reductions in underage purchases at vape shops were observed, but the results were not statistically significant (87).

Nguyen found that provincial bans on e-cigarette sales to minors were only partially effective (11). Youth in Canadian provinces with such bans were less likely to purchase products from grocery stores, convenience stores, and vape shops compared to provinces without bans, however, these policies also led to increased dependence on social sources for obtaining e-cigarettes (11). Kong and colleagues reported no change in the prevalence of youth obtaining e-cigarettes from commercial sources in Connecticut after similar restrictions were introduced (39). Importantly, the Alberta data used in this thesis were collected during a pandemic. A national cross-sectional study in the United States suggest that during the COVID-19 pandemic, vape shops and online platforms were regularly selling vaping products to underage youth (88). One qualitative study investigating vape sourcing in the United States found common themes, including the inconsistencies or absence of online age verification, the use of third-party software requiring users to submit a photo of their ID, and tactics to bypass age verification at the point of delivery (89).

The results from Chapter 3, which found no significant change in vape purchases among underage students in grades 7–11 following the policy implementation, underscore the need for strict interventions such as mandatory training for all staff and more random compliance checks accompanied by greater penalties to address enforcement gaps and regulatory inconsistencies. Without these measures, minimum legal sales age policies may have limited effectiveness in reducing youth vaping. Connell et al. found that while various policy methods such as age restrictions, flavour bans, and sales restrictions are commonly implemented, their effectiveness may be enhanced when these strategies are enacted together rather than individually (125).

Graham-DeMellow et al. suggest that strengthening national and local policy enforcement through fines and license confiscation is warranted for facilities selling e-cigarettes to minors (41). In 2018, the U.S. Food and Drug Administration undertook a landmark enforcement initiative targeting the sale and promotion of e-cigarettes to youth (126). This effort included issuing over 1,300 warning letters and fines to retailers who illegally sold these products to minors as part of a nationwide, undercover operation (126). This served as a notable example of a substantial enforcement action that could be replicated to further protect youth.

An enforcement team in Alberta is authorized to issue fines, though the strictness and frequency of their enforcement actions are unknown (15). South Zone serves over 300,000 Albertans and covers a 65,500 km^2 area from the southern British Columbo to Saskatchewan border (127). Despite this, only two enforcement officers oversee compliance of the ~250 retailers under the TSVRA. While local Public Health Inspectors are present in the region, they do not have the same enforcement authority under the legislation to issue fines. The limited number of enforcement officers in rural areas may impact adherence to the legislation. Travel constraints for the officer, or communication among retailers could limit effectiveness if businesses warn one another of incoming inspections. Enforcement officers should be available for unannounced inspections at any time, but logistical challenges such as long travel distances can create gaps in enforcement coverage.

These findings can be framed within a socio-ecological model, which provides a multi-level approach to understanding and addressing e-cigarette use among youth. Unlike models that focus primarily on individual skills and characteristics or proximal social influences, the socio-ecological model incorporates environmental and policy-level factors that shape behaviours (128). Policies and environments that support healthful choices empower individuals to make decisions that enhance their well-being (128).

Applying this framework to youth vaping and purchasing behaviours offers a more comprehensive understanding of the factors influencing these actions. Green et al. discussed the success of tobacco control initiatives, which can inform strategies for reducing youth vaping (129). Their findings emphasize the importance of multilevel interventions, noting that population-level change is unlikely to result solely from education or motivation at the individual level (129). Braak et al. describe the need to address social sources of vaping products, with 10–20% of youth in three high-income countries reported giving money to a third party to purchase vaping products on their behalf (83). Addressing social sources requires incorporating the interpersonal level of the socio-ecological model, which focuses on relationships that influence behaviour. Achieving widespread change in social norms and support for environmental and policy initiatives often requires sustained efforts over decades (129).

In developing effective strategies to reduce youth vaping, Alberta can also consider a multi-tiered approach informed by Frieden's health impact pyramid. This framework places interventions addressing socioeconomic determinants of health at its foundation, emphasizing the importance of systemic efforts to shape environments that support healthy choices (130). The subsequent levels include altering the context to make healthy behaviours the default, implementing long-lasting protective measures, providing clinical interventions, and, at the top of the pyramid, offering counselling and educational initiatives (130). Public health actions that alter the context, such as stricter enforcement of retail compliance and age verification, can create default decisions that are health-enhancing while requiring minimal individual effort. However, as Frieden highlights, systemic actions at the base of the pyramid may be controversial and requires public engagement and cross-sector collaboration to build support for such measures (130).

The channels through which youth most frequently notice vaping-related messages, including social media, schools, and television/radio, offer insights for targeting future public health campaigns (131). Situated within the context of the health impact pyramid, these campaigns align with the higher tiers, focusing on education and counselling to influence individual behaviour. While these efforts play an important role in addressing youth vaping, they require ongoing engagement, which can be more challenging to achieve compared to interventions lower on the pyramid that shape the broader social and environmental context.

East et al. found that many campaigns in Canada and the United States were heavily focused on the negative consequences of vaping, which could reinforce misperceptions that vaping is as harmful as smoking (131). To expand reach, future campaigns should adopt a more balanced approach that highlights both the risks of youth vaping and the relative harm reduction benefits of vaping compared to smoking for adults. To achieve sustained public health improvements across the population, these efforts should also be combined with broader policy.

Richard Edwards, a New Zealand researcher discussed the recently approved smoke-free generation policy in the UK (132). This law restricts anyone born after January 1, 2009, from ever buying tobacco products legally in their lifetime to. He emphasized that the policy should be part of a comprehensive approach incorporating other measures to limit the availability, affordability, addictiveness, and appeal of smoked tobacco products. His description aligns with the socio-ecological model, highlighting the need for interventions at multiple levels to effectively restrict the behaviour and enhance the policy's success.

Policy-level interventions, such as those examined in this study, are especially promising for fostering sustained behaviour change. While community-level interventions often struggle with long-term maintenance, policy changes have the potential to create durable, population-wide impacts (128,130). By addressing vaping behaviours through a socio-ecological and health impact pyramid lens, policymakers can develop targeted, multi-level strategies that address both individual and systemic factors contributing to youth vaping. Additionally, policymakers should integrate strategies that strengthen retailer accountability, such as mandatory training for all employees on age verification, requirement of point-of-sale technology that prompt for ID verification, more random compliance checks, and greater penalties for non-compliance and in turn policies could better mitigate youth access to e-cigarettes and support healthier behaviours.

4.3 STRENGTHS AND LIMITATIONS

Strengths of this study include the use of large samples of data collected from students in a natural, school-based setting. The use of pre-calculated survey weights adjusts for non-response and sampling design, improving the generalizability of the findings to the broader student population. Response rates were strong with less than 5% of responses marked “not stated”. By comparing two time points (before and after the policy change), this study offers valuable insights into shifts in vaping behaviour following regulatory interventions.

Another strength of this thesis is its application of implementation science principles. Oh et al. claim that policy implementation science is underrepresented in research, and argue that prioritizing its place in research could improve population health outcomes (133). By evaluating a policy within real-world conditions, this approach emphasizes external validity, ensuring the findings are applicable to broader populations. Public health policies are often constructed with the goal of enhancing health outcomes, however, effective implementation, continuous outcome evaluation, and stakeholder engagement are fundamental for success (133). Additionally, implementation science provides an opportunity to explore how public health policies affect social determinants of health by investigating intended and unintended consequences (134).

Purtle et al. constructed four straightforward conceptualizations to think about in implementation science: policy as something to adopt, policy as something to implement, policy as context to understand, and policy as strategy to use (135). Policy refers to the strategies, actions, or inactions, developed by governments at any level to address issues that require a collective response to promote societal well-being and resolve pressing challenges (69). My research aligns most closely with the conceptualization of policy as 'the thing' to be operationalized. By evaluating the province-wide rollout of the vaping prevention policy, this study seeks to generate knowledge on optimizing policy implementation to enhance population health. Such an approach ensures that evidence-supported policies are not only adopted but also effectively applied in real-world conditions.

Limitations include use of cross-sectional data. There were changes in vaping behaviour and purchases patterns among youth in the time span examined, making it difficult to determine the extent to which the changes in outcomes can be attributed to the policy change that took place in July of 2021. Changes in vaping prevalence and underage purchases could be influenced by other factors, such as evolving trends over time. The COVID-19 pandemic shifted some youth from in-person classes to virtual settings, potentially contributing to the observed prevalence shift. Reduced peer-group gathers, availability disruption of substances, and increased time spent at home with parents are suggested to have contributed to the observed decline in prevalence of substance use among youth according to the systematic review by Layman et al. (29).

A systematic review by Reiter et al. highlighted that because of the complexity of population-level regulations, all included studies had an elevated risk of bias (10). Evaluating the impact of such policies is challenging because external factors such as cultural norms, shifting product availability, and disruptions from events like COVID-19 can confound results making it difficult to isolate the policy’s true impact. This susceptibility can potentially compromise internal validity of the study. While efforts were made to address confounding variables during analysis, ensuring the complete identification and accurate measurement of all variables presents challenges. Not all identified confounders were available or consistent between survey waves, leaving residual confounding a concern.

An additional limitation of this research lies in the challenges associated with comparing sex and gender variables between survey waves. In 2018/19, Health Canada provided data on sex at birth, while in 2021/22, this was replaced with gender identity. To ensure comparability, I removed 6.5% of respondents in the 2021/22 wave who selected "another gender or gender not stated," which may have excluded important insights about LGBTQ+ individuals.

While a response rate of 60% is generally considered acceptable for most research studies, Alberta's rate in 2018/19 was only slightly above this threshold at 62%, potentially introducing some non-response bias (1,25). Detailed evaluation of response rates for the 2021/22 survey is not yet publicly available. However, given that response rates in Alberta for the 2014/15 and 2016/17 cycles were 59% and 75%, respectively, it is reasonable to expect that the 2021/22 response rate will be near or above the acceptable threshold (26,27). Non-response can be attributed to parent/guardian refusals, student refusals, or absenteeism the day of implementation.

Underestimation of risky health behaviours may occur due to non-response bias (28). A cross-sectional study of adolescent health revealed that voluntary sampling yielded lower rates of alcohol and tobacco consumption compared to mandatory sampling (28). Youth who did not respond may have had past 30-day vape use or purchased products underage, thereby reducing the true prevalence. Additionally, social desirability bias could affect self-reported data, with respondents potentially underreporting vaping behaviours or purchases to avoid judgment, despite the anonymity of the survey (136). This bias may further influence the accuracy of the reported prevalence.

Another limitation is the lack of representation of truly rural participants with approximately 85% of respondents classified as urban and only 15% as rural. Participants in a census metropolitan area and tracked or non-tracked census agglomeration were coded as urban, while the remaining categories were coded as rural (1). However, communities with fewer than 1,000 individuals, which fall under Statistics Canada's definition of rural areas, were likely excluded due to class sizes smaller than 20 students (21). Consequently, the ~15% "rural" participants may not be genuinely representative of rural Alberta. Those in rural areas may have different accessibility to products; for example, a village with only one gas station acting as a one-stop shop may contribute to higher prevalence if that facility sells to minors. This is problematic as research has shown higher rates of youth vaping in rural areas than urban, warranting further investigation (96).

Analyzing population-wide policy is a difficult task. Public policy and its subsequent analysis are rarely simple matters, as the problems stemming from the policy are often complex, multifaceted, and subject to controversy (33). These issues frequently lack clear solutions, making impartial analysis essential for assessing key information (33). However, the analysis relied on a publicly available cross-sectional dataset due to considerations of accessibility and time, reducing its quality. While certain variables could be quantitatively controlled for like sex/gender and grade level, more abstract variables such as the COVID-19 pandemic, media and political trends, and social norms were not accounted for. The study compared prevalence rates of different groups of youth at two time points, recognizing that a population wide legislative intervention had occurred in between.

The time lag in federal data release posed a limitation. Although data for the 2023/24 cycle should theoretically have been collected, it was not yet available, limiting the opportunity for a more comprehensive and robust post-policy analysis. Millikan states that the goal of social science research is to enhance and expand policymakers' capacity to make informed decisions, rather than simply offering them answers (137). Despite its limitations, I believe my thesis has the potential to enhance policymakers' decision-making capacity.

4.4 FUTURE RESEARCH DIRECTION

Unfortunately, the “rural” participants in this study were not truly representative of rural Alberta. Rural and remote communities often face heightened vulnerabilities and increased health risks due to a combination of factors, including limited access to resources, social programs, and affordable healthcare services (30). Additional challenges, such as restricted access to higher education, job opportunities, and technological infrastructure like high-speed internet, exacerbate these disparities (30). Previous research highlights that policy effectiveness often varies between rural and urban areas, with youth in rural regions exhibiting higher rates of vaping compared to their urban counterpart (96). To address these unique challenges, future research should prioritize surveying youth in genuinely rural areas, enabling the development of tailored strategies to prevent vaping and promote health equity in these communities.

Research conducted in the U.S. identified numerous methods adolescents use to bypass these restrictions, including retailers simply asking if they were of legal age, relaxed verification at small local stores, repeated visits to familiar shops, the use of fake IDs, and a notable contrast where large chains, such as 7 – Eleven, maintained stricter verification procedures (89). In depth details about the methods used in these transactions in Canada are unclear. To address this gap, future studies should include survey questions specifically designed to uncover how youth are able to evade age restrictions. For instance, students who self-report buying products from retail sources could be asked follow-up questions such as: *How did you purchase the product?* with response options such as: a) the store is known to not check ID, b) I used a fake ID, c) I know the employee, among others. Collecting this type of data would provide awareness to inform interventions and enhance enforcement strategies at the retail level. While research from the United States has examined policy awareness at retail facilities, similar studies are lacking in Canada (138).

LGBTQ+ individuals often encounter unique health disparities and systemic discrimination. Johnson et al. found that transgender and sexual minority youth were more likely to use tobacco products than their nonminority peers, while García-Ramírez and colleagues reported greater reductions in lifetime e-cigarette use among sexual minority youth following California's T21 policy (17,18). These findings suggest that certain subgroups may benefit more from policy interventions. However, without detailed data on these groups, it is difficult to design and implement targeted interventions that address their unique needs. This gap highlights the importance of collecting and analyzing comprehensive data on diverse populations in future research to ensure equitable public health outcomes.

A study by Allcot and Rafkin in the United States examined the regulatory challenges of e-cigarettes, modelling optimal taxation and subsidy strategies based on health impacts and consumer behaviour (139).They found that the demand for e-cigarettes is relatively elastic, indicating that price changes significantly affect consumer behaviour, while also proposing potential subsidies if vaping is found to be a safer alternative to smoking (139). They suggest that e-cigarette taxes should be higher than what is currently standard, based on the health concerns provided by public health experts and highlight the need for future research focusing on the uninternalized externalities and internalities associated with vaping (139).

Alberta can leverage these insights to refine enforcement and support strategies for youth by tailoring compliance monitoring efforts, adopting evidence-based interventions, and fostering cross-sector collaboration. By learning from the successes and challenges observed in other jurisdictions, Alberta can develop more effective and targeted measures to reduce youth vaping and strengthen the overall impact of its policies. Additionally, the socio-ecological model and health impact pyramid should be used to guide efforts to address youth behaviour by considering factors at all levels of influence, from individual choices to systemic interventions that alter the context to support healthier decisions.

To further assess the long-term effects of these policies, longitudinal studies are needed to follow the same youth over multiple years pre- and post-policy implementation. These studies should incorporate mixed methods, including open-ended qualitative questions to gather detail on how and why youth are exactly changing their behaviours. Qualitative m can help identify common themes and assess key motivators of behaviour change. This approach would provide deeper understanding into how policy changes shape behaviours over time and inform the development of sustained, impactful strategies.

4.5 CONCLUSION

This thesis examined youth vaping prevalence and underage purchase of vaping products before and after Alberta's province-wide vaping prevention policy was enacted. Using data collected from students in a natural setting, this research contributes to the growing body of evidence on the external validity of policy interventions in real-world conditions. There was a 5.1% reduction in youth vaping prevalence over the 27-month study period, with more pronounced decreases among older youth and males. In Chapter 3, underage purchases of vaping products showed a small, non-significant overall increase, with opposing trends between males and females. While these findings were not statistically significant, they suggest the importance of exploring potential sex- and gender-specific strategies to better understand and address unique patterns in vaping behaviour and access.

The study also highlighted persistent challenges, such as the high prevalence of youth vaping and underage purchases, which indicate that additional measures are necessary to address these behaviours comprehensively. Policy interventions alone may be insufficient without effective enforcement mechanisms, such as rigorous age verification practices at the retail level. Future research should focus on evaluating compliance and enforcement practices to identify gaps and strengthen policy implementation. By addressing these gaps, refining policies to target diverse populations, and incorporating longitudinal or quasi-experimental methods in future research, Alberta and other regions can advance efforts to protect youth from the harms of vaping and create a healthier, more equitable environment.

REFERENCES

1. Burkhalter R, Thompson-Haile A, Cooke M. 2018/2019 Canadian Student Tobacco, Alcohol and Drugs Survey Microdata User Guide. Waterloo Ontartio Propel Cent Popul Health Impact Univ Waterloo. 2019;1–39.

2. Health Canada & CCI Research Inc. Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS) 2021-2022 PUMF User Guide [Internet]. 2022. Available from: https://opencanada.blob.core.windows.net/opengovprod/resources/41cdfd12-e1b3-4083-bc8e-24afb4b04409/cstads-2021-2022-pumf-user-guide.pdf?se=2024-08-12T19%3A43%3A20Z&sp=r&sv=2019-07-07&sr=b&sig=Bxd9AkHOCMUYKDbF37f7s5qwONmSeu514px2p3n3pSw%3D

3. US Department of Health and Human Services. E-cigarette use among youth and young adults: A report of the Surgeon General. 2016.

4. Cherian SV, Kumar A, Estrada-Y-Martin RM. E-cigarette or vaping product-associated lung injury: a review. Am J Med. 2020;133(6):657–63.

5. Government of Canada. Canadian Tobacco and Nicotine Survey (CTNS): summary of results for 2019. 2020.

6. Government of Alberta. Tobacco, Smoking and Vaping Reduction Act [Internet]. T-3.8 2005. Available from: https://kings-printer.alberta.ca/570.cfm?frm_isbn=9780779844111&search_by=link

7. Browner WS, Newman TB, Cummings SR, Grady DG. Designing clinical research. Lippincott Williams & Wilkins; 2022.

8. Government of Canada. Summary of results for the Canadian Student Tobacco, Alcohol and Drugs Survey 2018-19. 2019.

9. Government of Canada. Summary of results for the Canadian Student Tobacco, Alcohol and Drugs Survey 2021-22. 2024.

10. Reiter A, Hébert-Losier A, Mylocopos G, Filion KB, Windle SB, O'Loughlin JL, et al. Regulatory Strategies for Preventing and Reducing Nicotine Vaping Among Youth: A Systematic Review. Am J Prev Med. 2023;

11. Nguyen HV. Association of Canada's Provincial Bans on Electronic Cigarette Sales to Minors With Electronic Cigarette Use Among Youths. JAMA Pediatr. 2020;174(1):e193912–e193912.

12. Cole AG, Aleyan S, Battista K, Leatherdale ST. Trends in youth e-cigarette and cigarette use between 2013 and 2019: insights from repeat cross-sectional data from the COMPASS study. Can J Public Health. 2021;112:60–9.

13. Cole AG, Short M, Aalaei N, Gohari M, Leatherdale ST. Identifying changes in e-cigarette use among a longitudinal sample of Canadian youth e-cigarette users in the COMPASS cohort study, 2017/18–2018/19. Addict Behav Rep. 2022;16:100458.

14. Wong SL, Shields M, Leatherdale S, Malaison E, Hammond D. Assessment of validity of self-reported smoking status. Health Rep. 2012;23(1):D1.

15. Government of Alberta. Reducing smoking and vaping - rules and enforcement [Internet]. 2024. Available from: https://www.alberta.ca/reducing-smoking-and-vaping-rules-and-enforcement

16. Kcomt L, Evans-Polce RJ, Veliz PT, Boyd CJ, McCabe SE. Use of cigarettes and e-cigarettes/vaping among transgender people: results from the 2015 US Transgender Survey. Am J Prev Med. 2020;59(4):538–47.

17. García-Ramírez G, Islam S, Wharton MK, Grube JW. Associations of California's Tobacco 21 minimum sales age law with tobacco use among sexual minority adolescents: a trends analysis. Nicotine Tob Res. 2022;24(11):1834–9.

18. Johnson SE, O'Brien EK, Coleman B, Tessman GK, Hoffman L, Delahanty J. Sexual and gender minority US youth tobacco use: Population Assessment of Tobacco and Health (PATH) study wave 3, 2015–2016. Am J Prev Med. 2019;57(2):256–61.

19. Szklo M, Nieto FJ. Epidemiology: beyond the basics. Jones & Bartlett Publishers; 2014.

20. Egger S, Watts C, Dessaix A, Brooks A, Jenkinson E, Grogan P, et al. Parent's awareness of, and influence on, their 14–17-year-old child's vaping and smoking behaviours; an analysis of 3242 parent–child pairs in Australia. Addict Behav. 2024;150:107931.

21. Government of Canada SC. Dictionary, Census of Population, 2021 – Rural area (RA) [Internet]. 2021 [cited 2024 Jun 7]. Available from: https://www12.statcan.gc.ca/census-recensement/2021/ref/dict/az/definition-eng.cfm?ID=geo042

22. Digitale JC, Martin JN, Glymour MM. Tutorial on Directed Acyclic Graphs. J Clin Epidemiol. 2022 Feb;142:264–7.

23. Craig P, Cooper C, Gunnell D, Haw S, Lawson K, Macintyre S, et al. Using natural experiments to evaluate population health interventions: new Medical Research Council guidance. J Epidemiol Community Health. 2012;

24. Porta M. A dictionary of epidemiology. Oxford university press; 2014.

25. Fincham JE. Response rates and responsiveness for surveys, standards, and the Journal. Am J Pharm Educ. 2008;72(2).

26. Rynard V, Burkhalter R, Manske S. 2014/15 Canadian Student, Tobacco, Alcohol and Drugs Survey Microdata User Guide. Waterloo Ontartio Propel Cent Popul Health Impact Univ Waterloo. 2015;

27. Burkhalter R, Thompson-Haile A, Manske S. 2016/17 Canadian Student, Tobacco, Alcohol and Drugs Survey Microdata User Guide. Waterloo Ontartio Propel Cent Popul Health Impact Univ Waterloo. 2017;1–51.

28. Cheung KL, Ten Klooster PM, Smit C, de Vries H, Pieterse ME. The impact of non-response bias due to sampling in public health studies: A comparison of voluntary versus mandatory recruitment in a Dutch national survey on adolescent health. BMC Public Health. 2017;17:1–10.

29. Layman HM, Thorisdottir IE, Halldorsdottir T, Sigfusdottir ID, Allegrante JP, Kristjansson AL. Substance use among youth during the COVID-19 pandemic: a systematic review. Curr Psychiatry Rep. 2022;24(6):307–24.

30. Leimbigler B, Li EPH, Rush KL, Seaton CL. Social, political, commercial, and corporate determinants of rural health equity in Canada: an integrated framework. Can J Public Health. 2022;113(5):749–54.

31. Sanson-Fisher RW, D'Este CA, Carey ML, Noble N, Paul CL. Evaluation of systems-oriented public health interventions: alternative research designs. Annu Rev Public Health. 2014;35:9–27.

32. Leatherdale ST. Natural experiment methodology for research: a review of how different methods can support real-world research. Int J Soc Res Methodol. 2019;22(1):19–35.

33. Kraft ME, Furlong SR. Public policy: Politics, analysis, and alternatives. Cq Press; 2020.

34. Government of Saskatchewan. The Tobacco and Vapour Products Control Act [Internet]. Available from: file:///C:/Users/ath50/Downloads/T14-1%20(2).pdf

35. Government of Northwest Territories. TOBACCO AND VAPOUR PRODUCTS CONTROL ACT [Internet]. SNWT 2019,C.31. Available from: https://www.justice.gov.nt.ca/en/files/legislation/tobacco-and-vapour-products/tobacco-and-vapour-products.a.pdf

36. Government of Northwest Territories. Banning the Sale of flavoured Vapour Products [Internet]. Government of the Northwest Territories; [cited 2024 Apr 18]. Available from: https://www.gov.nt.ca/en/newsroom/banning-sale-flavoured-vapour-products

37. Harlow AF, McConnell RS, Barrington-Trimis JL. Underage E-Cigarette Purchasing and Vaping Progression Among Young Adults. J Adolesc Health. 2023;72(2):260–6.

38. Roeseler A, Vuong TD, Henriksen L, Zhang X. Assessment of underage sales violations in tobacco stores and vape shops. JAMA Pediatr. 2019;173(8):795–7.

39. Kong G, Morean ME, Cavallo DA, Camenga DR, Krishnan-Sarin S. Sources of electronic cigarette acquisition among adolescents in Connecticut. Tob Regul Sci. 2017;3(1):10.

40. Meyers MJ, Delucchi K, Halpern-Felsher B. Access to tobacco among California high school students: the role of family members, peers, and retail venues. J Adolesc Health. 2017;61(3):385–8.

41. Graham-DeMello A, Hoek J, Drew J. How do underage youth access e-cigarettes in settings with minimum age sales restriction laws? A scoping review. BMC Public Health. 2023;23(1):1809.

42. Government of Canada CI of HR. Notice of Upcoming Funding Opportunity: Moving Upstream: Structural Determinants of Health Catalyst Grants - CIHR [Internet]. 2024 [cited 2024 Apr 22]. Available from: https://cihr-irsc.gc.ca/e/53883.html

43. Kinouani S, Leflot C, Vanderkam P, Auriacombe M, Langlois E, Tzourio C. Motivations for using electronic cigarettes in young adults: A systematic review. Subst Abuse. 2020;41(3):315–22.

44. Husari A, Shihadeh A, Talih S, Hashem Y, El Sabban M, Zaatari G. Acute exposure to electronic and combustible cigarette aerosols: effects in an animal model and in human alveolar cells. Nicotine Tob Res. 2016;18(5):613–9.

45. Kaisar MA, Prasad S, Liles T, Cucullo L. A decade of e-cigarettes: limited research & unresolved safety concerns. Toxicology. 2016;365:67–75.

46. Hwang JH, Lyes M, Sladewski K, Enany S, McEachern E, Mathew DP, et al. Electronic cigarette inhalation alters innate immunity and airway cytokines while increasing the virulence of colonizing bacteria. J Mol Med. 2016;94:667–79.

47. Barrington-Trimis JL, Urman R, Leventhal AM, Gauderman WJ, Cruz TB, Gilreath TD, et al. E-cigarettes, cigarettes, and the prevalence of adolescent tobacco use. Pediatrics. 2016;138(2).

48. Chapman S, Bareham D, Maziak W. The gateway effect of e-cigarettes: reflections on main criticisms. Nicotine Tob Res. 2019;21(5):695–8.

49. Mylocopos G, Wennberg E, Reiter A, Hébert-Losier A, Filion KB, Windle SB, et al. Interventions for preventing e-cigarette use among children and youth: a systematic review. Am J Prev Med. 2023;

50. DiCasmirro J, Tranmer J, Davison C, Woo K, Ross-White A, Hubeny M, et al. Public health interventions to prevent adolescent vaping: a scoping review protocol. JBI Evid Synth. 2023;21(11):2272–8.

51. Krishnasamy VP. Update: characteristics of a nationwide outbreak of e-cigarette, or vaping, product use–associated lung injury—United States, August 2019–January 2020. MMWR Morb Mortal Wkly Rep. 2020;69.

52. Chadi N, Moore-Hepburn C, Beno S, Richmond SA. Vaping-related injury and illness among Canadian children and adolescents: A one-time survey of paediatric providers. BMJ Paediatr Open. 2020;4(1).

53. Do MT, McFaull SR, Guttman L, Ghandour L, Hardy J. Original quantitative research-Strengthening surveillance of consumer products in Canada: the vaping example. Health Promot Chronic Dis Prev Can Res Policy Pract. 2020;40(10):309.

54. Government of Canada. Consumer Product Safety Program Annual Surveillance Report: 2021. 2022.

55. Health Canada. Vapers Panel Survey to Measure Attitudes and Behaviours Regarding Vaping Products [Internet]. 2019. Report No.: POR 083-18. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://epe.lac-bac.gc.ca/100/200/301/pwgsc-tpsgc/por-ef/health/2019/083-18-e/report.pdf

56. Health Canada. Exploratory Research on Youth Vaping [Internet]. 2020. Report No.: 069–19. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://epe.lac-bac.gc.ca/100/200/301/pwgsc-tpsgc/por-ef/health/2020/069-19-e/report.pdf

57. Pound CM, Coyle D. A cost-utility analysis of the impact of electronic nicotine delivery systems on health care costs and outcomes in Canad. Health Promot Chronic Dis Prev Can Res Policy Pract. 2022;42(1):29.

58. Coyle D. Implementing a smoke-free generation policy for Canada: estimates of the long-term impacts. Health Promot Chronic Dis Prev Can Res Policy Pract. 2025;45(1):39.

59. Collins LG, Lindsay D, Lal A, Doan T, Schüz J, Jongenelis M, et al. A systematic review of the modelling and economic evaluation studies assessing regulatory options for e-cigarette use. Int J Drug Policy. 2024;129:104476.

60. Chan GC, Stjepanović D, Lim C, Sun T, Shanmuga Anandan A, Connor JP, et al. Gateway or common liability? A systematic review and meta-analysis of studies of adolescent e-cigarette use and future smoking initiation. Addiction. 2021;116(4):743–56.

61. Becker TD, Rice TR. Youth vaping: a review and update on global epidemiology, physical and behavioral health risks, and clinical considerations. Eur J Pediatr. 2022;181(2):453–62.

62. Kundu A, Kouzoukas E, Zawertailo L, Fougere C, Dragonetti R, Selby P, et al. Scoping review of guidance on cessation interventions for electronic cigarettes and dual electronic and combustible cigarettes use. Can Med Assoc Open Access J. 2023;11(2):E336–44.

63. Crane LA, Asdigian NL, Fitzgerald MD. Looking Cool, Doing Tricks, Managing Stress, and Nicotine Addiction: Youth Perspectives on Nicotine Vaping and Implications for Prevention. Am J Health Promot. 2023;37(7):964–74.

64. Notley C, Gentry S, Cox S, Dockrell M, Havill M, Attwood AS, et al. Youth use of e-liquid flavours—a systematic review exploring patterns of use of e-liquid flavours and

associations with continued vaping, tobacco smoking uptake or cessation. Addiction. 2022;117(5):1258–72.

65. Pepper JK, Farrelly MC, Watson KA. Adolescents' understanding and use of nicotine in e-cigarettes. Addict Behav. 2018;82:109–13.

66. East KA, Hitchman SC, McNeill A, Thrasher JF, Hammond D. Social norms towards smoking and vaping and associations with product use among youth in England, Canada, and the US. Drug Alcohol Depend. 2019;205:107635.

67. Government of Canada. Canadian Student Tobacco, Alcohol and Drugs Survey: detailed tables for 2014-15 [Internet]. 2016. Available from: https://www.canada.ca/en/health-canada/services/canadian-student-tobacco-alcohol-drugs-survey/2014-2015-supplementary-tables.html#t12

68. Reid JL, Burkhalter R, Kasza K, Seo YS, East K, Hyland A, et al. Minimum legal age laws and perceived access to cigarettes, e-cigarettes, and other substances among youth in Canada, England, and the United States: 2017-2021. Int J Drug Policy. 2023;115:104003.

69. Birkland TA. An introduction to the policy process: Theories, concepts, and models of public policy making. Routledge; 2019.

70. Alberta Justice. A Guide to the Legislative Process - Acts and Regulations [Internet]. 2008. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://open.alberta.ca/dataset/523e5bc6-047a-472c-97eb-74b6ff2cfe8f/resource/6eb82779-eb1b-4044-8fa6-140839e86391/download/leg-process-manual-nov-2008.pdf

71. Glasgow S, Schrecker T. The double burden of neoliberalism? Noncommunicable disease policies and the global political economy of risk. Health Place. 2016;39:204–11.

72. Popay J, Whitehead M, Hunter DJ. Injustice is killing people on a large scale—but what is to be done about it? J Public Health. 2010;32(2):148–9.

73. Chan GC, Gartner C, Lim C, Sun T, Hall W, Connor J, et al. Association between the implementation of tobacco control policies and adolescent vaping in 44 lower-middle, upper-middle, and high-income countries. Addiction. 2022;117(8):2296–305.

74. Olson LT, Coats EM, Rogers T, Brown EM, Nonnemaker J, Ross AM, et al. Youth tobacco use before and after local sales restrictions on flavored and menthol tobacco products in Minnesota. J Adolesc Health. 2022;70(6):978–84.

75. Hammond D, Rynard VL, Reid JL. Changes in prevalence of vaping among youths in the United States, Canada, and England from 2017 to 2019. JAMA Pediatr. 2020;174(8):797–800.

76. Hammond D, Reid JL, Rynard VL, Fong GT, Cummings KM, McNeill A, et al. Prevalence of vaping and smoking among adolescents in Canada, England, and the United States: repeat national cross sectional surveys. bmj. 2019;365.

77. Government of Canada. Tobacco and Vaping Products Act. The Minister of Justice; 2024.

78. Government of Nunavut. Tobacco and Smoking Act - c.20 [Internet]. c. 20. Available from: https://www.nunavutlegislation.ca/en/statutes/tobacco-and-smoking-act-c20

79. Campaign for a smoke-free Alberta. NEW ALBERTA REGULATIONS FAIL TO PROTECT YOUTH FROM FLAVOURED VAPING PRODUCTS [Internet]. 2021. Available from: https://protectalbertakids.ca/2021/06/26/new-alberta-regulations-fail-to-protect-youth-from-flavoured-vaping-products/

80. Alberta Health Services. Alberta Tobacco Retailer Toolkit: Preventing Illegal Tobacco and Vape Sales to Alberta Youth. 2022 p. 36.

81. Yan D, Wang Z, Laestadius L, Mosalpuria K, Wilson F, Yan A, et al. A systematic review for the impacts of global approaches to regulating electronic nicotine products. J Glob Health. 2023; 13: 04076.

82. Taylor E, O'Connor S, Schwartz R. E-Cigarette MInimum Age: Theory, Evidence and Regulatory Policy [Internet]. Ontario Tobacco Research Unit; 2021. Available from: https://www.otru.org/wp-content/uploads/2021/09/minimum-age-april-2021-FINAL.pdf

83. Braak D, Michael Cummings K, Nahhas GJ, Reid JL, Hammond D. How are adolescents getting their vaping products? Findings from the international tobacco control (ITC) youth tobacco and vaping survey. Addict Behav. 2020;105:N.PAG-N.PAG.

84. McKeganey N, Russell C, Katsampouris E, Haseen F. Sources of youth access to JUUL vaping products in the United States. Addict Behav Rep. 2019;10:100232.

85. Pepper JK, Coats EM, Nonnemaker JM, Loomis BR. How do adolescents get their e-cigarettes and other electronic vaping devices? Am J Health Promot. 2019;33(3):420–9.

86. Agaku IT. A rapid evaluation of the US federal tobacco 21 (T21) law and lessons from statewide T21 policies: findings from population-level surveys. Prev Chronic Dis. 2022;19.

87. Schiff S, Liu F, Cruz TB, Unger JB, Cwalina S, Leventhal A, et al. E-cigarette and cigarette purchasing among young adults before and after implementation of California's tobacco 21 policy. Tob Control. 2021;30(2):206–11.

88. Gaiha SM, Lempert LK, Halpern-Felsher B. Underage youth and young adult e-cigarette use and access before and during the coronavirus disease 2019 pandemic. JAMA Netw Open. 2020;3(12):e2027572–e2027572.

89. Schiff SJ, Kechter A, Simpson KA, Ceasar RC, Braymiller JL, Barrington-Trimis JL. Accessing vaping products when underage: a qualitative study of young adults in Southern California. Nicotine Tob Res. 2021;23(5):836–41.

90. Sindelar JL. Regulating vaping—policies, possibilities, and perils. N Engl J Med. 2020;382(20):e54.

91. Peters DH, Adam T, Alonge O, Agyepong IA, Tran N. Implementation research: what it is and how to do it. Bmj. 2013;347.

92. Handley MA, Lyles CR, McCulloch C, Cattamanchi A. Selecting and improving quasi-experimental designs in effectiveness and implementation research. Annu Rev Public Health. 2018;39:5–25.

93. Bharmal N, Derose KP, Felician M, Weden MM. Understanding the upstream social determinants of health. Calif RAND. 2015;1–18.

94. Elliott M. Regression Methods in Biostatistics: Linear, Logistic, Survival, and Repeated Measures Models Edited by Vittinghoff, E., Glidden, DV, Shiboski, SC, and Mcculloch, CE. 2006;

95. Statistics Canada. Canada at a Glace, 2022 [Internet]. 2022. Available from: https://www150.statcan.gc.ca/n1/pub/12-581-x/2022001/sec7-eng.htm

96. Dai H, Chaney L, Ellerbeck E, Friggeri R, White N, Catley D. Rural-urban differences in changes and effects of Tobacco 21 in youth e-cigarette use. Pediatrics. 2021;147(5).

97. Manitoba Health. Government of Manitoba. Smoking or vaping in public places. Available from: https://www.gov.mb.ca/health/publichealth/environmentalhealth/protection/smoking.html#:~:text=Research%20shows%20that%20secondhand%20smoke,vaping%20in%20enclosed%20public%20places.

98. Government of Ontario. Government of Ontario. 2021. Where you can't smoke or vape in Ontario. Available from: https://www.ontario.ca/page/where-you-cant-smoke-or-vape-ontario

99. Government of Canada. Regulating tobacco and vaping products [Internet]. 2024. Available from: https://www.canada.ca/en/health-canada/services/smoking-tobacco/regulating-tobacco-vaping.html

100. Marion JW, Strand A, Baldridge E. Changes in student behaviors and policy opinion regarding E-cigarettes at a Kentucky University from 2014 to 2018. Prev Med Rep. 2021;22:101364.

101. Mahalik JR, Levine Coley R, McPherran Lombardi C, Doyle Lynch A, Markowitz AJ, Jaffee SR. Changes in health risk behaviors for males and females from early adolescence through early adulthood. Health Psychol. 2013;32(6):685.

102. Schneider SK, Buka SL, Dash K, Winickoff JP, O'Donnell L. Community reductions in youth smoking after raising the minimum tobacco sales age to 21. Tob Control. 2016;25(3):355–9.

103. Knoll LJ, Leung JT, Foulkes L, Blakemore SJ. Age-related differences in social influence on risk perception depend on the direction of influence. J Adolesc. 2017;60:53–63.

104. Dahl RE. Adolescent brain development: a period of vulnerabilities and opportunities. Keynote address. Ann N Y Acad Sci. 2004;1021(1):1–22.

105. Government of Canada. Alcohol and Drug Use among Students in Canada, 2023–24 [Internet]. 2025. Available from: https://www.canada.ca/en/health-canada/services/canadian-student-tobacco-alcohol-drugs-survey/2023-2024-key-findings.html

106. Macinko J, Silver D. Impact of New York City's 2014 increased minimum legal purchase age on youth tobacco use. Am J Public Health. 2018;108(5):669–75.

107. Hamberger ES, Halpern-Felsher B. Vaping in adolescents: epidemiology and respiratory harm. Curr Opin Pediatr. 2020;32(3):378.

108. Substance Abuse and Mental Health Services Administration (SAMHSA). Reducing vaping among youth and young adults. 2020;

109. Christiani DC. Vaping-induced acute lung injury. N Engl J Med. 2020;382(10):960–2.

110. Chadi N, Vyver E, Belanger RE. Protecting children and adolescents against the risks of vaping. Paediatr Child Health. 2021;26(6):358–65.

111. Romm KF, Wang Y, Schleicher NC, Pannel A, Williams R, Berg CJ, et al. Rates of age verification for cigarette and e-cigarette purchases as a function of state T21 laws before and after implementation of the federal T21 law in the United States. Nicotine Tob Res. 2023;25(7):1386–90.

112. Bright CL, Sacco P, Kolivoski KM, Stapleton LM, Jun HJ, Morris-Compton D. Gender differences in patterns of substance use and delinquency: A latent transition analysis. J Child Adolesc Subst Abuse. 2017;26(2):162–73.

113. Newcomb ME, Heinz AJ, Birkett M, Mustanski B. A longitudinal examination of risk and protective factors for cigarette smoking among lesbian, gay, bisexual, and transgender youth. J Adolesc Health. 2014;54(5):558–64.

114. Schulte MT, Ramo D, Brown SA. Gender differences in factors influencing alcohol use and drinking progression among adolescents. Clin Psychol Rev. 2009;29(6):535–47.

115. O'Brien SF, Bierman KL. Conceptions and perceived influence of peer groups: Interviews with preadolescents and adolescents. Child Dev. 1988;1360–5.

116. Dishion TJ, Tipsord JM. Peer contagion in child and adolescent social and emotional development. Annu Rev Psychol. 2011;62(1):189–214.

117. Chen P, Jacobson KC. Developmental trajectories of substance use from early adolescence to young adulthood: Gender and racial/ethnic differences. J Adolesc Health. 2012;50(2):154–63.

118. Isakson K, Jarvis P. The adjustment of adolescents during the transition into high school: A short-term longitudinal study. J Youth Adolesc. 1999;28(1):1–26.

119. Alves De Castro C, Carthy A. Social media influencers (SMIs) in context: A literature review. 2021;

120. Milicic S, DeCicca P, Pierard E, Leatherdale ST. An evaluation of school-based e-cigarette control policies' impact on the use of vaping products. Tob Induc Dis. 2018;16:1–9.

121. Reading CL, Wien F. Health inequalities and the social determinants of Aboriginal peoples' health. National Collaborating Centre for Aboriginal Health Prince George, BC; 2009.

122. Sikorski C, Leatherdale S, Cooke M. Tobacco, alcohol and marijuana use among Indigenous youth attending off-reserve schools in Canada: cross-sectional results from the Canadian Student Tobacco, Alcohol and Drugs Survey. Promot Santé Prév Mal Chron Au Can. 2019;39(6).

123. Fairchild A, Healton C, Curran J, Abrams D, Bayer R. Evidence, alarm, and the debate over e-cigarettes. Science. 2019;366(6471):1318–20.

124. Berridge V, Fairchild AL, Morphett K, Gartner C, Hall W, Bayer R. E-cigarettes: a framework for comparative history and policy. Addiction. 2024;

125. O'Connell M, Kephart L. Local and state policy action taken in the United States to address the emergence of e-cigarettes and Vaping: a scoping review of literature. Health Promot Pract. 2022;23(1):51–63.

126. U.S. Food and Drug Administration. FDA takes new steps to address epidemic of youth e-cigarette use, including a historic action against more than 1,300 retailers and 5 major manufacturers for their roles perpetuating youth access [Internet]. 2018. Available from: https://www.fda.gov/news-events/press-announcements/fda-takes-new-steps-address-epidemic-youth-e-cigarette-use-including-historic-action-against-more#:~:text=In%20the%20largest%20coordinated%20enforcement,mortar%20and%20online%20stores%20this

127. Statistics Canada. Census Profile, 2016 Census [Internet]. 2024. Available from: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=HR&Code1=4831&Geo2=PR&Code2=48&SearchText=South%20Zone&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=4831&TABID=1&type=0

128. Sallis JF, Owen N, Fisher E. Ecological models of health behavior. Health Behav Theory Res Pract. 2015;5(43–64).

129. Green LW, Orleans CT, Ottoson JM, Cameron R, Pierce JP, Bettinghaus EP. Inferring strategies for disseminating physical activity policies, programs, and practices from the successes of tobacco control. Am J Prev Med. 2006;31(4):66–81.

130. Frieden TR. A framework for public health action: the health impact pyramid. Am J Public Health. 2010;100(4):590–5.

131. East K, Taylor E, Simonavičius E, Nottage M, Reid JL, Burkhalter R, et al. Noticing education campaigns or public health messages about vaping among youth in the United States, Canada and England from 2018 to 2022. Health Educ Res. 2024;39(1):12–28.

132. Kirby T. Smoke-free generation a step closer in the UK. Lancet Oncol. 2025;26(1):19.

133. Oh A, Abazeed A, Chambers DA. Policy implementation science to advance population health: the potential for learning health policy systems. Front Public Health. 2021;9:681602.

134. Emmons KM, Chambers DA. Policy implementation science–an unexplored strategy to address social determinants of health. Ethn Dis. 2021;31(1):133.

135. Purtle J, Moucheraud C, Yang LH, Shelley D. Four very basic ways to think about policy in implementation science. Implement Sci Commun. 2023;4(1):111.

136. Tourangeau R, Yan T. Sensitive questions in surveys. Psychol Bull. 2007;133(5):859.

137. Millikan MF. Inquiry and policy. Sci Public Policy Evol Policy Sci Pt 1. 1999;1:250.

138. Zhang X, Vuong TD, Andersen-Rodgers E, Roeseler A. Evaluation of California's 'Tobacco 21'law. Tob Control. 2018;27(6):656–62.

139. Allcott H, Rafkin C. Optimal regulation of e-cigarettes: Theory and evidence. Am Econ J Econ Policy. 2022;14(4):1–50.

APPENDIX 1: QUESTION #22 ON THE 2018/19 SURVEY AND QUESTIONS 32, 33, & 34 ON THE 2021/22 SURVEY

#22) On how many of the last 30 days did you use an e-cigarette (vape, vape pen, tank & mod, e-juice)?

(1) Daily or almost daily

(2) Less than daily, but at least once a week

(3) Less than weekly, but at least once a month

(4) Less than monthly

(5) Not at all

(6) I don't know

(99) Not stated

#32) In the last 30 days, how often did you vape an e-liquid or pod with nicotine?

(1) Daily

(2) Less than daily, but at least once a week

(3) Less than weekly, but at least once in the last 30 days

(4) Tried, but did not use in the last 30 days

(5) I have never tried

(99) Not Stated

#33) In the last 30 days, how often did you vape an e-liquid or pod without nicotine?

#34) In the last 30 days, how often did you vape an e-liquid or pod but you did not know what it contained?(1,2)

APPENDIX 2: QUESTION #23 ON THE 2018/19 SURVEY AND QUESTIONS 40 & 41 ON THE 2021/22 SURVEY

#23 Where do you usually get your e-cigarettes and supplies (vape, vape pen, tank & mod, e-juice)? (Mark all that apply).

(1) I do not use e-cigarettes

(2) I buy them from a vape shop

(3) I buy them from a convenience store

(4) I ask someone to buy them for me

(5) I buy them online

(6) A family member gives them to me

(7) A friend gives them to me

(8) Someone else gives them to me

(9) I use my mother's, father's, or siblings' without their permission

(10) I use someone else's without their permission

(11) Other

(99) Not stated

#40 Where do you usually get your vaping devices (vape, vape pen, tank & mod)?

(1) I do not vape

(2) I buy them from a vape shop (in person, not online)

(3) I buy them from a convenience store

(4) I ask someone to buy them for me

(5) I buy them online

(6) A family member gives them to me (bought, borrowed, shared)

(7) A friend gives them to me (bought, borrowed, shared)

(8) Someone else gives them to me (bought, borrowed, shared)

(9) I use my mother’s, father’s, or siblings’ without their permission

(10) I use someone else’s without their permission

(11) Other

(99) Not stated

#41 Where do you usually get your e-liquids or pods?

(1) I do not vape

(2) I buy them from a vape shop (in person, not online)

(3) I buy them from a convenience store

(4) I ask someone to buy them for me

(5) I buy them online

(6) A family member gives them to me (bought, borrowed, shared)

(7) A friend gives them to me (bought, borrowed, shared)

(8) Someone else gives them to me (bought, borrowed, shared)

(9) I use my mother’s, father’s, or siblings’ without their permission

(10) I use someone else’s without their permission

(11) Other

(99) Not stated

(1,2)

APPENDIX 3: DETERMINATION OF ETHICS REVIEW REQUIREMENT

UNIVERSITY OF ALBERTA

RESEARCH ETHICS OFFICE

2-01 North Power Plant (NPP)
11312 - 89 Ave NW
Edmonton, Alberta, Canada T6G 2N2
www.uab.ca/reo

April 22, 2024

Amanda Hepp
Faculty/Department: Faculty of Health Sciences - University of Lethbridge
Email: amanda.hepp@uleth.ca

Dear Amanda Hepp:

RE: Determination of Ethics Review Requirement

Thank you for requesting a determination for your project: "ASSESSING THE IMPACT OF POLICY ON UNDERAGE VAPING IN ALBERTA:". We have reviewed the details provided in your submission received on 2024-04-17 20:02:28.

The project that you have outlined meets one of the conditions described under Chapter 2 of TCPS2 (2022) as an activity that does not require REB review and, unless you make changes to the project, ethics approval is not needed. As such, the project has been determined to be outside of the REB's mandate. However, please note that if data is collected for the purposes of such activities but later proposed for research purposes, it would be considered secondary use of information not originally intended for research, and at that time may require REB review.

This research uses publicly available data and therefore ethics review is not required.

Sincerely,

Charmaine N. Kabatoff
Senior Officer, REB for
Anthony S. Joyce, PhD
Chair, Health Research Ethics Board - Health Panel