Changes in Cannabis Consumption Behaviors in relation to Policy and Public Health Developments and Respiratory Health of Emerging Adults in Canada

by

Susan J. Yousufzai

A thesis submitted to the
School of Graduate and Postdoctoral Studies in partial
fulfillment of the requirements for the degree of

Master of Health Sciences in Community, Public and Population Health

Faculty of Health Sciences

University of Ontario Institute of Technology (Ontario Tech University)

Oshawa, Ontario, Canada

July 2021

THESIS EXAMINATION INFORMATION

Submitted by: **Susan J. Yousufzai**

Master of Health Sciences in **Community, Public and Population Health**

Thesis title: **Changes in Cannabis Consumption Behaviors in relation to Policy and Public Health Developments and Respiratory Health of Emerging Adults in Canada**

An oral defense of this thesis took place on June 30, 2021 in front of the following examining committee:

Examining Committee:

Chair of Examining Committee	Dr. Manon Lemonde
Research Supervisor	Dr. Caroline Barakat
Examining Committee Member	Dr. Adam Cole
Examining Committee Member	Dr. Mika Nonoyama
Thesis Examiner	Dr. Amir Mostaghim

The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ABSTRACT

Cannabis use appears to be more common among emerging adults (EA) compared to other age groups in Canada. Substance use or misuse peaks during emerging adulthood and may be influenced by political and public health deviations. This study aimed to (1) examine trends in frequency and quantity of cannabis consumption among EA before and after: legalization of cannabis in Canada, the "e-cigarette or vaping product use associated lung injury" (EVALI) outbreak, and COVID-19; and (2) to examine sex-specific differences in cannabis use and associations with respiratory symptoms. There was a continuous and gradual increasing trend in quantity and frequency of smoking and vaping cannabis over time. Quantity and frequency of consumption was higher among males than females. Frequency of vaping only/dual consumption may be protective of respiratory symptoms among females. Increased consumption demonstrates a need for policy measures to address excessive use following political changes and during public health events.

Keywords: cannabis; emerging adults; legalization; EVALI; COVID-19

AUTHOR'S DECLARATION

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I authorize the University of Ontario Institute of Technology (Ontario Tech University) to lend this thesis to other institutions or individuals for the purpose of scholarly research. I further authorize University of Ontario Institute of Technology (Ontario Tech University) to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research. I understand that my thesis will be made electronically available to the public.

The research work in this thesis that was performed in compliance with the regulations of Research Ethics Board/Animal Care Committee under **REB Certificate number/Animal care certificate** [REB#15880].

Susan Yousufzai

STATEMENT OF CONTRIBUTIONS

I performed the majority of the synthesis, testing of the data, and writing of this thesis research. Dr. Caroline Barakat and I took part in conceiving and designing the study. I collected, analyzed and conducted the statistical analysis of the data.

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

ACKNOWLEDGEMENTS

As I sit here writing this piece I think about the times I imagined getting to this point and the many people who have supported me and inspired me along the way. First and foremost, I would like to extend my deepest gratitude to my amazing supervisor, Dr. Caroline Barakat. The opportunities you have given me, your support throughout this process, and the belief you have had in me, encouraged me to believe in my academic pursuit. Your knowledge and guidance throughout this process have been nothing short of inspirational. I look forward to all our future potential endeavors.

Thank you to my supportive committee members, Dr. Adam Cole and Dr. Mika Nonoyama. Your time, guidance and consistent feedback throughout all the revisions have been immensely appreciated - I have learned so much from you both.

I would also like to thank my friends in the Community, Public and Population Health program who have shared their experiences with me, and for all the great times we spent in the grad room together. Special thanks to IK for listening to my rants and all our chats – I am grateful to have started your journey with you and that you were able to see this all through with me.

Thank you to my siblings for continuously encouraging and believing in me (but always distracting me), and for all those times you asked about when I would be done; I can finally say that I am! I know we will keep achieving great things together. To my parents; thank you for pushing me to always strive for better and the opportunity to dream. Mom, I cannot thank you enough for the warm meals and snacks you always brought me. I hope that I continue to make you proud.

I am also indebted to my amazing friends for reminding me to believe in myself when things got tough, and for all our fun times together when I needed a break! Last but not least, thank you to EW for celebrating the little successes with me, making me laugh and being my number one cheerleader. I am extremely lucky to have such a great support system.

Finally, thank you to all those who have supported this research and the awesome Faculty of Health Sciences at Ontario Tech that have made this journey possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations	Definitions
EA	Emerging adults
THC	Δ-9-tetrahydrocannabinol
CBD	Cannabidiol
CBR	Cannabis receptors
EVD	Electronic vaping devices
COVID-19	Coronavirus
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
EVALI	E-cigarette or vaping-product use associated lung illnesses
CDC	Centers for Disease Control and Prevention
ACE2	Angiotensin-converting enzyme II
FVC	Forced Vital Capacity
FEV_1	Forced Expiratory Volume Exhaled for 1 Second
COPD	Chronic obstructive pulmonary disease
LCHD	Life Course Health Development Framework
HBM	Health Belief Model
CUD	Cannabis use disorder
PTSD	Post-traumatic stress disorder
LRCUG	lower-risk cannabis use guidelines

Chapter 1. Introduction

1.1 Background

Cannabis (or marijuana) is one of the most popular and "normalized" substance that was transformed from an illicit to licit substance in Canada (Hathaway et al., 2018; Leos-Toro, 2002; Osborne & Fogel, 2016). The implementation of the *Cannabis Act* in 2018, represents a seismic shift in Canadian drug policy, permitting the legal consumption and production of cannabis for both recreational and medicinal purposes. Public health priorities have developed in Canada, Uruguay, and multiple states in the USA that have legalized recreational cannabis use, in order to generate a comprehensive understanding of cannabis use within the context of policy changes (Crépault et al., 2016; Fischer et al., 2017). Researchers have highlighted that loosening cannabis policies in favor of recreational use would result in increased consumption among vulnerable populations, translating into various health-risks (Halladay et al., 2018; Parnes et al., 2018; Watson & Erickson, 2019), though understanding the impact of legalization is ongoing (Hammond et al., 2020; Rotermann, 2020).

1.1.1 Cannabis plant

Cannabis is the generic name for the substance derived from the female flowering plant, generally identified by its different species: *Cannabis Sativa*, *Cannabis Indica* and *Cannabis Ruderalis* (Ribeiro & Ind, 2016). The plant produces two major active compounds; cannabidiol (CBD) and the main psychoactive ingredient, Δ-9-tetrahydrocannabinol, commonly known as THC, which induces a 'high' by acting on endogenous cannabis receptors (CB1Rs and CB2Rs) in the brain (Atakan, 2012; Gloss, 2015). Although the pharmacological effects of cannabis are complex due to the wide distribution of the endocannabinoid system in the brain and expression

of CBRs in other areas of the body, such as the peripheral nervous system and immune cells (Atakan, 2012). In addition, over centuries of cultivation and societal acceptance, cannabis has undergone selective breeding over time, resulting in diversification of cannabis compounds and increased potency of THC content (Atakan, 2012).

1.1.2 Cannabis consumption exposure profiles

There are many preparations of cannabis used in varying ways to achieve desired effects (Atakan, 2012; Giroud et al., 2015; Gloss, 2015). This thesis will focus on preparations and methods that involve inhalation through routes of smoking and vaping, which will be referred to as cannabis consumption exposure profiles. Cannabis consumption exposure profiles include **routes** of inhalation used to consume cannabis (i.e., smoking or vaping), the **method** (mode/device) employed, along with the most common corresponding **forms** of cannabis (dried herb, hash/hashish, concentrates, and vaping oil) smoked or vaped (Figure 1.1).

Cannabis use varies depending on routes of administration, through means of inhaling, ingesting or administering topically. Inhalation remains the most popular method of consumption, particularly smoking alone (Russel et al., 2018), and more recently with vaping (referred to as dual use) (Jones et al., 2016). Traditional methods of inhalation include smoking combusted herbal cannabis products, using paper and mechanical apparatuses such as a blunt, joint, bong, or pipe. Novel methods of inhalation, such as vaping, involves inhaling an aerosol mixture of vapor produced by non-combustion of dried herb, oil, and concentrate preparations (e.g., shatter, crumble, wax) using both portable and non-portable electronic vaping devices (EVD) (Biehl & Burnham; Giroud et al., 2015). However, consuming concentrate compounds of cannabis are often administered using methods specifically designed for them, such as dab rigs or dap pens.

The newly derived mechanism whereby concentrates are heated and inhaled involves a process known as “dabbing”, which allows for a single ‘hit’ of high in THC cannabis products, such as butane hash oil (BHO) to be delivered using a dab rig. Dab rigs are water pipe devices that closely resemble a traditional bong but require the addition of other components (i.e., nail, dome and dabber) to complete the consumption process. Specifically, the desired concentrate amount is heated on a hot platform (known as the nail) where it immediately vaporizes and passes through the nail into the water pipe before being inhaled (Chan et al., 2017; Troutt & Didonato, 2017). In this case, the method of dabbing is sometimes considered a form of “vaping” cannabis rather than a form of combustion, in which the cannabis is directly burned (Russel et al., 2018). Dab pens, on the other hand, are vaping devices designed exclusively for several cannabis concentrate compounds which are placed in specialized chambers within the device, where it is heated. Unlike the dab rig, the dab pen allows for titrating the dose of cannabis concentrate delivered through multiple intakes (Sagar et al., 2018).

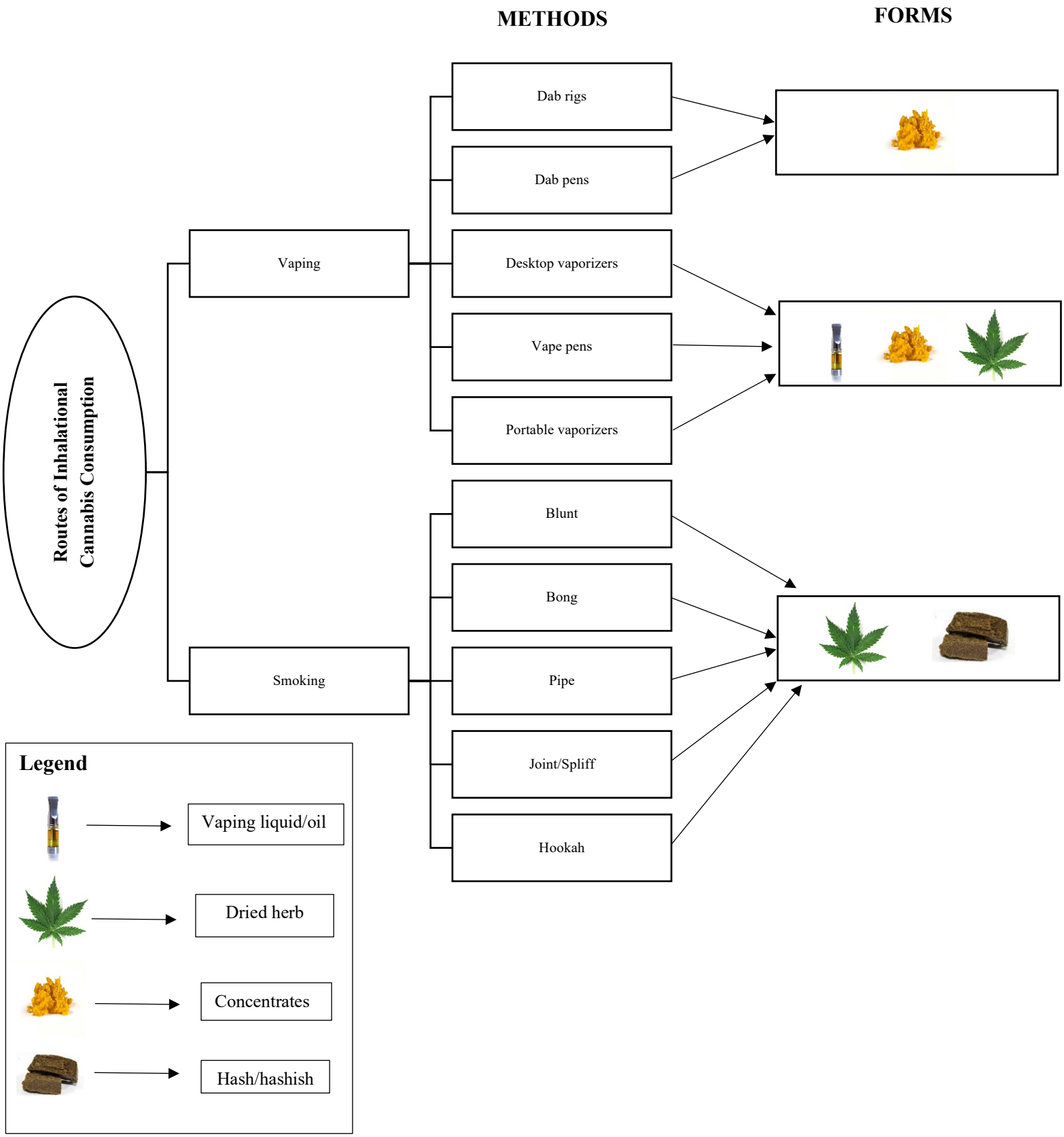


Figure 1.1. ***Cannabis exposure profiles:*** *inhalational methods of cannabis consumption (i.e. smoking and vaping), and the associated modes used for the different forms.* ***Routes of Inhalational Cannabis Consumption:*** *Vaping; Smoking.* ***Methods of Vaping****:* Desktop Vaporizer; E-cigarettes; Vaporizers; Vape Pens; Dab Pens. ***Methods of Smoking:*** Blunt; Bong; Hookah; Joint; Spliff*;* Pipe; Dabbing. ***Forms*** include: Herbal Cannabis (i.e. plant buds, hashish) and Concentrates (i.e. Vape juice/e-liquid juice, Honey Butane Oil, Hash oil, Wax, Shatter).

1.1.3 Determinants of cannabis consumption

Research highlights the importance of examining associations of human developmental transitions with determinants of cannabis use (Guttmanova et al., 2019). In addition to the dynamic changes in cultural reforms surrounding cannabis, determinants of cannabis consumption are theorized to include a complex interplay of individual (biological, genetic, personality) environmental and social factors (peer and community variables) (Bickel et al., 2014; Ter Bogt et al., 2014). In the substance use research field, the consideration of subpopulations in relation to age, sex-and gender-related factors are important to acknowledge in developing harm-reduction guidelines and effective programming (Greaves & Hemsing, 2020).

Emerging adulthood

Emerging adulthood is a life stage between 18 and 29 years old, with a focus on ages 18 through to 25 years (Arnett et al., 2014). Individuals in this stage of life are thought to be in a period of extended adolescence, that includes reduced parental monitoring and shying away from full engagement in the responsibilities of adulthood (Arnett, 2000). Thus, it is considered a distinct developmental period from adolescence and adulthood, characterized by a unique set of challenges involving instability and exploration before making enduring life-long changes. This period can also entail engaging in various health-risk behaviors, such as substance use (Arnett et al., 2014; Stone et al., 2012). Inability to achieve the socially constructed expectations of adulthood following this period, such as financial stability or strong interpersonal relationships have been associated with acute and increasing substance use (Stone et al., 2012). Indeed, this age cohort has been noted as a critical period in relation to cannabis and other substance use (Halladay et al., 2018; Stone et al., 2012; SAMHSA Office of Applied Studies, 2009).

Emerging adults (EA) may be particularly vulnerable to policy change, though there is limited evidence on cannabis consumption trends in this group (Johnson & Guttmannova, 2019). EA represent the most common population cohort to use and experiment with cannabis (Halladay et al., 2018; Parnes et al., 2018; Guttmanova et al., 2019). Historical evidence shows a steady increase in cannabis use across all age groups in Ontario, particularly, among EA. For example, self-reported prevalence of cannabis consumption among EA increased from 21.4% in 1997 to 40.4% in 2012 (Crépault et al., 2016; Ialomiteanu et al., 2012). Recent evidence on national cannabis trends in Canada following legalization in 2019, indicates that the prevalence of past three-month consumption was 33.3% for individuals 18 to 24-years. Although this level remains constant from before legalization, it exceeded the rates for people in all other age groups (ranging from 5.9% to 24.4%). Moreover, EA (20 to 24) in Canada have the highest rate of experimenting with novel methods of consumption, such as vaping (Mehra et al., 2019).

Gender and sex-related factors

In this research, the term 'gender' signified social behaviors of cannabis exposure profiles among males and females, while 'sex' referred to physiological characteristics of respiratory health.

Existing empirical research on high consumer cannabis groups, including adolescents and EA, suggests that gender (as an expression of sociocultural driven influences and constructed norms), is a key predictor of cannabis use patterns (Greaves & Hemsing, 2020; Ter Bogt et al., 2014). Traditionally, males have a higher prevalence of using cannabis than females. However, recent evidence indicates a narrowing gender-gap in consumption (Greaves & Hemsing, 2020; Cutter et al., 2016). In fact, the first indication of this trend was seen in Canada between 2014/2015, when females were equally likely to report past-year cannabis use as males (Leos-

Toro et al., 2019). This narrowing difference may reflect changes in social perceptions and perceived risks associated with altering cannabis policies, normalization, and decreased stigma, particularly for females (Greaves & Hemsing, 2020).

Recent research indicates variation in cannabis consumption methods used by gender, in which females were more likely to use edible forms and other methods that required less preparation (Cuttler et al., 2016). Correspondingly, gender preferences for certain methods and forms of consumption may impact health-related outcomes linked to sex-specific biological factors. For example, evidence suggests a higher sensitivity to cannabis associated effects, problematic use and withdrawal in females compared to males (Cooper & Craft, 2018; Crocker & Tibbo, 2017; Greaves & Hemsing, 2020). In addition, cannabis smoking is generally considered a critical risk-factor for adverse respiratory health outcomes, although there is scarce research examining differences in sex-related outcomes (Ghasemiesfe et al., 2018).

1.1.4 Respiratory health risks

The respiratory system is the primary target of any potentially harmful effects of toxins and constituents produced by cannabis smoking combustion, and in aerosol emissions produced by vaping devices. Cannabis consumption behaviors involving inhalation of combusted or vaped forms may have differing effects on respiratory health, given differences in gender-consumption patterns (Greaves & Hemsing, 2020), in lung characteristic between sexes (Carey et al., 2009), and in the lung development of young cannabis users (Coates et al., 2013).

Lung Development

Human lung development is determined and differentiated by the regulatory effects of sex hormones, and expression of key genes. Starting from an early age, the physiology of male and female lungs is very different. Maturation of the airways and lungs continues through

childhood and into adolescence. For the most part, males continue to have larger lungs and conducting airways than females (Carey et al., 2009). In adulthood the volume of adult female lungs is typically 10-12% smaller than that of males who have the same height and age (LoMauro & Aliverti, 2018). Lung growth and volume increases until 18 to 20 years of age in females, and 20 to 24 years of age in males. The aforementioned physiological characteristics have been linked to epidemiological differences in the incidence, susceptibility and severity of several lung diseases in relation to sex (Carey et al., 2007).

Respiratory symptoms in relation to cannabis consumption behaviors

The effects of different cannabis smoking methods on respiratory health has been scarcely studied. Some studies suggest that the characteristics of the smoke inhaled may be altered depending on the mode of administration. For example, using a water bong decreases the concentration of inhaled carcinogenic compounds (Ribeiro & Ind, 2016). Similarly, using a vaporizer as a route of inhalation, has been promoted as a safer method to use cannabis given the potential decrease of carcinogenicity in comparison to smoking (Lee et al., 2016).

It is imperative to examine the effects of various routes and measures (frequency, quantity) of cannabis consumption on respiratory symptoms in relation to gender and sex-specific differences among young cannabis users, especially considering there are differences in social behaviors of cannabis use across genders (Greaves & Hemsing, 2020), and physiological sex differences in lung function (LoMauro & Aliverti, 2018).

Smoking cannabis

While tobacco and cannabis smoke share similar carcinogenic properties, they are distinct in many ways including maneuvers used to inhale the combusted product, the butt-length to which it is smoked, and the temperature levels of the smoke (Ribeiro & Ind, 2016). In addition,

cannabis strains containing varying THC concentrations have been found to have bronchodilator agonists and antagonists, however, the research is inconclusive (Ribeiro & Ind, 2018). Since cannabis is the second most smoked substance, after tobacco, the extant literature focuses on the effects of cannabis smoking on respiratory health (Ghasemiesfe et al., 2018; Ribeiro & Ind, 2016).

Habitual cannabis smoking increases the incidence of respiratory symptoms linked to chronic bronchitis, such as chronic cough, sputum production, and wheeze (Ghasemiesfe et al., 2018; Martinasek et al., 2016); similar to symptoms experienced among tobacco smokers (Ribeiro & Ind, 2016). Some research shows females have higher sensitivity to tobacco smoke-related respiratory health outcomes compared to males (Langhammer et al., 2003). However, limited research has explored differences in sex-related respiratory symptoms in relation to cannabis use (Ghasemiesfe et al., 2018; Ribeiro & Ind, 2018). As cannabis is used in varying frequencies, quantities, and forms, it is critical to examine respiratory health and how it may be differently influenced from tobacco and in relation to gender-specific consumption behaviors.

Vaping cannabis

Literature on the effects of vaping cannabis alone on respiratory health is sparse given that vaping is a relatively new method of consumption. Some evidence points to fewer self-reported respiratory symptoms compared to smoking cannabis (Earleywine & Barnwell, 2007; Earleywine & Van Dam, 2010). However, the short-term and long-term health effects of using EVD as a method of cannabis consumption, are poorly understood (King et al., 2020). It is known that cannabis vaping liquids contain chemicals and additives, such as flavoring substances (e.g., terpenes) and thinning agents (i.e. propylene glycol, vegetable glycerin, vitamin-e acetate). These chemicals can lead to the production of carcinogenic constitutes such

as formaldehyde when heated, and have been speculated to cause the outbreak of lung-related illnesses referred to as "e-cigarette or vaping product use associated lung injury" (EVALI) (Chand et al., 2020; Troutt & DiDonato, 2017).

1.1.5 Policy and public health developments

Following the federal legalization of recreational cannabis use in Canada (October 17, 2018), subsequent public health developments have raised concerns in relation to the health outcomes associated with behavioral changes in cannabis consumption among at-risk and high consumer groups (Fischer et al., 2017; Halladay et al., 2018). This includes the EVALI outbreak, and the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) disease or 'COVID-19'. In light of the respiratory risks associated with EVALI and COVID-19, using methods of combustion and vaping to consume cannabis, have been considered risk-factors that may exacerbate complications associated with a COVID-19 infection and increase the susceptibility to lung injury (Borgonhi et al., 2021; Dubey et al., 2021).

The drug reform of legalizing cannabis for recreational use has been implemented with a cannabis policy framework that aims to maintain strict health-focused regulation (Lee et al., 2021). Despite advocated benefits, such as reducing illicit markets, and protecting youth by reducing access, challenges remain in attempting to control factors such as increasing prevalence and problematic cannabis use (Budney & Borodovsky, 2017; Fischer et al., 2017). Specifically, access to higher potency cannabis forms, new modes of administration, and reduced risk-perception of individuals previously practicing caution due to its previous illicit status may gauge curiosity (Watson & Erickson, 2019). For example, evidence suggests a growing trend of using cannabis concentrates as a result of legalization across the USA. These forms typically contain 60-85% THC content, compared to 10-12% found in plant material (Daniulaityte et al.,

2018). Such forms have been linked to mental health problems, and dependence (Hall & Degenhardt, 2015; Volkow et al., 2014). On the other hand, legalization has coincided with ample opportunity for the production of novel modes such as EVD, which can increase appeal, and pose reasonable concerns due to limited understanding of respiratory risks associated with the wide variety of vaping products and compounds (Braymiller et al., 2020; King et al., 2020).

In August 2019, the first cluster of EVALI outbreaks in the USA were reported to the Centers for Disease Control and Prevention (CDC) (King et al., 2020). The unprecedented outbreak was reported soon after in other countries, such as the UK and Canada, but to a lower degree. Although e-cigarettes were introduced in the USA in 2007, its rise to popularity occurred much later, during 2017-2018, especially among youth in USA and Canada (Fataar & Hammond, 2019; King et al., 2020). Diversification of vaping devices, flavors used in combination with nicotine, and the ability to consume aerosolized THC, which coincided with shifts in political domains, may have contributed to this increase in popularity and consequentially, EVALI. However, due to the initial uncertainty in relation to speculations of its cause, and limited cases in some countries, informative procedures that took place may not have been as effective to change perceptions of risk and intended public behavior to refrain from vaping (Morgan et al., 2021). In addition, while recent evidence suggests that perceptions of risk associated with e-cigarettes - typically used for nicotine consumption - are increasing (Kreslake et al., 2020; Morgan et al., 2021; Patel et al., 2020), it is not known whether these perceptions are shared among cannabis users and whether EVALI has dissuaded consumers from vaping cannabis products. Due to limited cases in Canada, it is also not known whether cannabis users were aware of EVALI. Thus, it is important to examine whether the spotlighting of this outbreak was

likely effective in changing perceived-risks among cannabis consumers to practice protective behaviors – especially in light of the subsequent emergence of COVID-19.

The current COVID-19 pandemic represents a massive global health crisis. This has led to large-scale societal behavior changes to control spread of infections, susceptibility, and increased health-risks associated with disease, which are implemented in alignment with recommendations from epidemiologists and public health experts (Van Bavel et al., 2020). Recommendations focused on modifiable risk-factors that can increase the risk of comorbidities, and severity of COVID-19, such as smoking and vaping. Due to known health risks associated with smoking, such as respiratory infections, and a weakened immune system, it follows that emerging research suggests progression of COVID-19 disease severity among hospitalized individuals that smoke or have a history of smoking tobacco (Karanasos et al., 2020). The risk of lung illnesses related to vaping also increased public health concerns, with some evidence indicating a higher risk of COVID-19 infection among individuals that vaped (Gaiha et al., 2020). However, the evidence remains controversial in determining the risk of hospitalization or severity of infection related to COVID-19 among individuals that smoke or vape cannabis. Nonetheless, it is important to note that while smoking or vaping may not be independent risk factors for COVID-19, these behaviors increase the risk of transmission and vulnerability to severe infection through associated comorbidities.

1.2 Research gaps and significance

Understanding the evolution of cannabis consumption behaviors is dependent upon examining the salience of human developmental transitions on use and corresponding health-risks (Guttmannova et al., 2019). Specifically, the dynamic interplay between cannabis-use risk factors, particularly perceptions of low harm, permissiveness, and cultural acceptance of

cannabis in relation to rapidly changing social contexts and external factors (i.e., public health developments) may influence the epidemiology and etiology of youth cannabis consumption in relation to gender and sex-specific health outcomes. An anticipated maladaptive response to social and environmental changes is substance use. Navigating through public-health threats and uncharted developments may influence excessive substance use, to cope with changing societal practices and subsequently, lead to noncompliance with public health directives (e.g., social-distancing) (Pfefferbaum & North, 2020). The accessibility of cannabis as a result of legalization provides multiple avenues and opportunities to influence consumption patterns, and may compound the increased vulnerability to substance increase during the pandemic.

While research into risk perception and behavioral responses during emerging infectious diseases is still evolving (Brug et al., 2009; Bults et al., 2011; Eaton and Kalichman, 2020), some evidence suggests that specific subpopulations are disproportionately at-risk, such as EA (Miller, 2020; Van et al., 2010). In fact, EA are more likely to defy public health directives (Miller, 2020), believe they are less susceptible to infection (Van et al., 2010), and are likely to resort to substance use during periods of stress (Halladay et al., 2018). Substance use/misuse is a problem that peaks during emerging adulthood (Stone et al., 2012), and may be further compounded in the context of extreme economic, social and community deviations, such as altering legislative policy changes (Parnes, et al., 2018), and pandemics (Dubey et al., 2020; Ornell et al., 2020). However, behavioral responses of at-risk populations, specifically in relation to cannabis use during these deviations is understudied. Research that examines cannabis consumption and associated risks, in the context of such emerging vulnerability factors is needed, especially for the EA populations. This includes examining the impact of socio-political and public health

developments on cannabis consumption, to help predict health-related behaviors and outcomes among at-risk individuals.

There is a particular need to further explore in research and clinical practice, sex and gender-based interactions in cannabis consumption behaviors and its effects (Greaves & Hemsing, 2020). In addition, the use of diverse cannabis methods to smoke or vape cannabis, and higher THC concentrated forms of cannabis, warrant tracking as factors that can impose reasonable concerns for young consumers (Watson & Erickson, 2019). The high prevalence of cannabis consumption among EA, increases vulnerability to respiratory health conditions associated with increased accessibility to cannabis following the federal policy change, associated risks correlated to public health crisis, and lung-illness outbreaks. Indeed, recent concerns have been raised about the convergence of vaping (and its effects) with COVID-19 infection, especially in young people, and in lieu of the similar systemic symptoms (e.g., fever, chills) and respiratory symptoms (cough, shortness of breath) associated with EVALI cases (Kazachkov & Pirzada, 2020).

Accordingly, the evolution of multiple developments in succession and their particular relevance to cannabis, including legalization of cannabis in Canada, evident health risks posed by cannabis products (EVALI), and unprecedented societal disruptions (COVID-19) are critical to examine. This work describing cannabis consumption trends and related health outcomes of cannabis consumption behaviors among EA, is timely and critical to aid public health planning strategies and interventions to inform lower risk guidelines to control recreational and therapeutic use.

1.4 Research questions and objectives

The primary research objective of this study is to better understand the cannabis use trends of EAs and how they may be affected by political and societal (e.g., public health events) developments. The second objective was to describe sex-specific profiles of cannabis consumption (i.e. vaping and/or smoking) and exposures such as modes, form, frequency, and quantity. The third objective was to examine significant sex-specific differences in respiratory symptoms in relation to predictors of exposure profiles (e.g. mode, form, frequency, and quantity) of cannabis consumption (i.e., vaping or smoking).

1. How did the legalization of cannabis in Canada, EVALI epidemic, and Coronavirus (COVID-19) pandemic influence cannabis consumption profiles (frequency, and quantity) for EA in Canada?
2. What are the differences in gender-specific behaviors in relation to cannabis consumption profiles (route of inhalation, method of use, form, frequency, and quantity)?
3. What are sex-specific predictors of respiratory symptoms in relation to cannabis exposure profiles (route of inhalation, method of use, form, frequency, and quantity)?

1.5 Hypotheses

H1: As compared to males, a higher proportion of females will increase their smoking and vaping frequency after legalization, but more females than males would decrease their frequency of consumption (vaping/smoking) following the declaration of EVALI and COVID-19.

H2: Quantity of consumption will increase among the overall population after legalization and COVID-19.

H3: Predictors of respiratory symptoms will be positively associated with dual use (smoking and vaping), frequency and quantity exposure among males due to higher reported history of prevalence of consumption among males in the literature.

References for Chapter 1

Arnett, J. J., Žukauskienė, R., & Sugimura, K. (2014). The new life stage of emerging adulthood at ages 18–29 years: implications for mental health. The Lancet Psychiatry, 1(7), 569–576. doi: 10.1016/s2215-0366(14)00080-7

Arnett, J. J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American psychologist*, *55*(5), 469.

Atakan, Z. (2012). Cannabis, a complex plant: different compounds and different effects on individuals. Therapeutic Advances in Psychopharmacology, 2(6), 241–254. doi: 10.1177/2045125312457586

Bickel, W. K., Johnson, M. W., Koffarnus, M. N., MacKillop, J., & Murphy, J. G. (2014). The behavioral economics of substance use disorders: reinforcement pathologies and their repair. *Annual review of clinical psychology*, *10*, 641–677. https://doi.org/10.1146/annurev-clinpsy-032813-153724

Biehl, J. R., & Burnham, E. L. (2015). Cannabis Smoking in 2015: A Concern for Lung Health? [Review]. 1(3), 596-606. doi: 10.1378/chest.15-0447

Borgonhi, E. M., Volpatto, V. L., Ornell, F., Rabelo-da-Ponte, F. D., & Kessler, F. H. P. (2021). Multiple clinical risks for cannabis users during the COVID-19 pandemic. *Addiction Science & Clinical Practice*, *16*(1), 1-4. https://doi.org/10.1186/s13722-021-00214-0

Braymiller, J. L., Barrington-Trimis, J. L., Leventhal, A. M., Islam, T., Kechter, A., Krueger, E. A., ... & McConnell, R. (2020). Assessment of Nicotine and Cannabis Vaping and Respiratory Symptoms in Young Adults. *JAMA network open*, *3*(12), e2030189-e2030189.

Brug, J., Aro, A. R., & Richardus, J. H. (2009). Risk perceptions and behaviour: towards pandemic control of emerging infectious diseases. DOI 10.1007/s12529-008-9000-x

Bults, M., Beaujean, D. J., de Zwart, O., Kok, G., van Empelen, P., van Steenbergen, J. E., ... & Voeten, H. A. (2011). Perceived risk, anxiety, and behavioural responses of the general public during the early phase of the Influenza A (H1N1) pandemic in the Netherlands: results of three consecutive online surveys. *BMC public health*, *11*(1), 1-13.

Chan, G. C., Hall, W., Freeman, T. P., Ferris, J., Kelly, A. B., & Winstock, A. (2017). User characteristics and effect profile of Butane Hash Oil: An extremely high-potency cannabis concentrate. *Drug and Alcohol Dependence*, 178, 32–38. doi: 10.1016/j.drugalcdep.2017.04.014

Crépault, J. F., Rehm, J., & Fischer, B. (2016). The Cannabis Policy Framework by the Centre for Addiction and Mental Health: a proposal for a public health approach to cannabis policy in Canada. *International journal on drug policy*, *34*, 1-4. http://dx.doi.org/10.1016/j.drugpo.2016.04.013

Cuttler, C., Mischley, L. K., & Sexton, M. (2016). Sex Differences in Cannabis Use and Effects: A Cross-Sectional Survey of Cannabis Users. Cannabis and cannabinoid research, 1(1), 166–175. doi:10.1089/can.2016.0010

Cooper, Z. D., & Craft, R. M. (2017). Sex-Dependent Effects of Cannabis and Cannabinoids: A Translational Perspective. Neuropsychopharmacology, 43(1), 34-51. doi:10.1038/npp.2017.140

Crocker, C. E., & Tibbo, P. G. (2018). The interaction of gender and cannabis in early phase psychosis. *Schizophrenia research*, *194*, 18-25. http://dx.doi.org/10.1016/j.schres.2017.04.046

Daniulaityte, R., Zatreh, M. Y., Lamy, F. R., Nahhas, R. W., Martins, S. S., Sheth, A., & Carlson, R. G. (2018). A Twitter-based survey on marijuana concentrate use. *Drug and alcohol dependence*, *187*, 155-159. https://doi.org/10.1016/j.drugalcdep.2018.02.033

Dubey, M. J., Ghosh, R., Chatterjee, S., Biswas, P., Chatterjee, S., & Dubey, S. (2020). COVID-19 and addiction. *Diabetes & metabolic syndrome*, *14*(5), 817–823. https://doi.org/10.1016/j.dsx.2020.06.008

Earleywine, M., & Barnwell, S. (2007). Decreased respiratory symptoms in cannabis users who vaporize. *Harm Reduction Journal*, 4(1), 11. doi: 10.1186/1477-7517-4-11

Earleywine, M., & Van Dam, N. T. (2010). Case studies in cannabis vaporization. *Addiction Research & Theory*, *18*(3), 243-249. doi: 10.3109/16066350902974753

Eaton, L. A., & Kalichman, S. C. (2020). Social and behavioral health responses to COVID-19: lessons learned from four decades of an HIV pandemic. *Journal of behavioral medicine*, *43*(3), 341-345. https://doi.org/10.1007/s10865-020-00157-y

Fataar, F., & Hammond, D. (2019). The prevalence of vaping and smoking as modes of delivery for nicotine and cannabis among youth in Canada, England and the United States. *International journal of environmental research and public health*, *16*(21), 4111. doi:10.3390/ijerph16214111

Fischer, B., Russell, C., Sabioni, P., Van Den Brink, W., Le Foll, B., Hall, W., ... & Room, R. (2017). Lower-risk cannabis use guidelines: a comprehensive update of evidence and recommendations. *American journal of public health*, *107*(8), e1-e12.

Gaiha, S. M., Cheng, J., & Halpern-Felsher, B. (2020). Association between youth smoking, electronic cigarette use, and COVID-19. *Journal of adolescent health*, *67*(4), 519-523. https://doi.org/10.1016/j.jadohealth.2020.07.002

Ghasemiesfe, M., Ravi, D., Vali, M., Korenstein, D., Arjomandi, M., Frank, J., ... & Keyhani, S. (2018). Marijuana use, respiratory symptoms, and pulmonary function: a systematic review and meta-analysis. *Annals of internal medicine*, *169*(2), 106-115.

Giroud, C., de Cesare, M., Berthet, A., Varlet, V., Concha-Lozano, N., & Favrat, B. (2015). E-cigarettes: a review of new trends in cannabis use. *International journal of environmental* research and public health, 12(8), 9988-10008. Doi:10.3390/ijerph120809988

Greaves, L., & Hemsing, N. (2020). Sex and gender interactions on the use and impact of recreational cannabis. *International journal of environmental research and public health*, *17*(2), 509. doi:10.3390/ijerph17020509

Gloss, D. (2015). An Overview of Products and Bias in Research. *Neurotherapeutics*, 12(4), 731–734. doi: 10.1007/s13311-015-0370-x

Guttmannova, K., Jones, A. A., Johnson, J. K., Oesterle, S., Johnson, R. M., & Martins, S. S. (2019). Using Existing Data to Advance Knowledge About Adolescent and Emerging Adult Marijuana Use in the Context of Changes in Marijuana Policies. *Prevention science: the official journal of the Society for Prevention Research*, *20*(2), 291–299. https://doi.org/10.1007/s11121-019-00991-w

Hall, W., & Degenhardt L (2015). High potency cannabis. *BMJ* 2015; 350:h1205 doi:10.1136/bmj.h1205

Halladay, J., Petker, T., Fein, A., Munn, C., & Mackillop, J. (2018). Brief interventions for cannabis use in emerging adults: protocol for a systematic review, meta-analysis, and evidence map. Systematic Reviews, 7(1). doi: 10.1186/s13643-018-0772-z

Hammond, D., Goodman, S., Wadsworth, E., Rynard, V., Boudreau, C., & Hall, W. (2020). Evaluating the impacts of cannabis legalization: the International Cannabis Policy Study. *International Journal of Drug Policy*, *77*, 102698. https://doi.org/10.1016/j.drugpo.2020.102698

Hathaway, A. D., Mostaghim, A., Erickson, P. G., Kolar, K., & Osborne, G. (2018). "It's really no big deal": the role of social supply networks in normalizing use of Cannabis by students at Canadian universities. *Deviant Behavior*, *39*(12), 1672-1680. https://doi.org/10.1080/01639625.2017.1411047

Ialomiteanu, A. R., Adlaf, E. M., Mann, R. E., & Rehm, J. (2011). Addiction and Mental Health Indicators Among Ontario Adults.

Jones, C.B., Hill, M.L., Pardini, D.A., Meier, M.H. (2016). Prevalence and correlates of vaping cannabis in a sample of young adults. *Psychol. Addict. Behav*. 30, 915–921. http://dx.doi.org/10.1037/adb0000217

Johnson, R. M., & Guttmannova, K. (2019). Marijuana use among adolescents and emerging adults in the midst of policy change: Introduction to the special issue. *Prevention Science, 20*(2), 179–184. https://doi.org/10.1007/s11121-019-0989-7

Karanasos, A., Aznaouridis, K., Latsios, G., Synetos, A., Plitaria, S., Tousoulis, D., & Toutouzas, K. (2020). Impact of smoking status on disease severity and mortality of hospitalized patients with COVID-19 infection: a systematic review and meta-analysis. *Nicotine & Tobacco Research*. doi:10.1093/ntr/ntaa107

Kazachkov, M., & Pirzada, M. (2020). Diagnosis of EVALI in the COVID-19 era. *The Lancet Respiratory Medicine*, *8*(12), 1169-1170

King, B. A., Jones, C. M., Baldwin, G. T., & Briss, P. A. (2020). The EVALI and youth vaping epidemics—implications for public health. *New England Journal of Medicine*, *382*(8), 689-691. doi: 10.1056/NEJMp1916171

Kreslake, J. M., Diaz, M. C., Shinaba, M., Vallone, D. M., & Hair, E. C. (2021). Youth and young adult risk perceptions and behaviours in response to an outbreak of e-cigarette/vaping-associated lung injury (EVALI) in the USA. *Tobacco Control*. http://dx.doi.org/10.1136/tobaccocontrol-2020-056090

Langhammer, A., Johnsen, R., Gulsvik, A., Holmen, T. L., & Bjermer, L. (2003). Sex differences in lung vulnerability to tobacco smoking. *European Respiratory Journal*, *21*(6), 1017-1023. doi: 10.1183/09031936.03.00053202

LoMauro, A., & Aliverti, A. (2018). Sex differences in respiratory function. *Breathe (Sheffield, England)*, *14*(2), 131–140. https://doi.org/10.1183/20734735.000318

Leos-Toro, C., Fong, G. T., Meyer, S. B., & Hammond, D. (2020). Cannabis health knowledge and risk perceptions among Canadian youth and young adults. *Harm reduction journal*, *17*(1), 1-13. https://doi.org/10.1186/s12954-020-00397-w

Leos-Toro, C., Rynard, V., Murnaghan, D., MacDonald, J. A., & Hammond, D. (2019). Trends in cannabis use over time among Canadian youth: 2004–2014. *Preventive medicine*, *118*, 30-37. https://doi.org/10.1016/j.ypmed.2018.10.002

Martinasek, M. P., McGrogan, J. B., & Maysonet, A. (2016). A systematic review of the respiratory effects of inhalational marijuana. *Respiratory care*, *61*(11), 1543-1551. doi: 10.4187/respcare.04846

Morgan, J. C., Silver, N., & Cappella, J. N. (2021). How did beliefs and perceptions about e-cigarettes change after national news coverage of the EVALI outbreak?. *PLOS ONE*, *16*(4), e0250908. doi: https://doi.org/10.1371/journal.pone.0250908

Mehra, V. M., Keethakumar, A., Bohr, Y. M., Abdullah, P., & Tamim, H. (2019). The association between alcohol, marijuana, illegal drug use and current use of E-cigarette among youth and young adults in Canada: results from Canadian Tobacco, Alcohol and Drugs Survey 2017. *BMC public health*, *19*(1), 1-10.

Miller, A. (2020, April 01). 'Everybody is susceptible': Why younger Canadians may be helping fuel the spread of COVID-19 | CBC News. Retrieved from https://www.cbc.ca/news/health/coronavirus-young-people-canada-1.5516936

Ornell, F., Moura, H. F., Scherer, J. N., Pechansky, F., Kessler, F. H. P., & von Diemen, L. (2020). The COVID-19 pandemic and its impact on substance use: Implications for prevention and treatment. *Psychiatry research*, *289*, 113096. doi: 10.1016/j.psychres.2020.113096.

Osborne, G. B., & Fogel, C. (2016). Perspectives on Cannabis Legalization Among Canadian Recreational Users. *Contemporary Drug Problems*, 44(1), 12-31. doi:10.1177/0091450916670393

Parnes, J. E., Smith, J. K., & Conner, B. T. (2018). Reefer madness or much ado about nothing? Cannabis legalization outcomes among young adults in the United States. International Journal of Drug Policy, 56, 116–120. doi: 10.1016/j.drugpo.2018.03.011

Patel, T., Karle, E., Gubeladze, T., Pentecost, G., & Krvavac, A. (2020). Patient Perception of Vaping in the Midst of the Electronic Cigarette and Vaping Product Associated Lung Injury (EVALI) Epidemic. *Missouri medicine*, *117*(3), 265–270.

Pfefferbaum, B., & North, C. S. (2020). Mental health and the Covid-19 pandemic. *New England Journal of Medicine*, *383*(6), 510-512. doi: 10.1056/NEJMp2008017

Ribeiro, L. I., & Ind, P. W. (2016). Effect of cannabis smoking on lung function and respiratory symptoms: a structured literature review. *NPJ primary care respiratory medicine*, *26*(1), 1-8.

Ribeiro, L., & Ind, P. W. (2018). Marijuana and the lung: hysteria or cause for concern? *Breathe*, 14(3), 196–205. doi: 10.1183/20734735.020418

Rotermann, M. (2020). What has changed since cannabis was legalized. *Health Rep*, *31*(2), 11-20.

Russell, C., Rueda, S., Room, R., Tyndall, M., & Fischer, B. (2018). Routes of administration for cannabis use - basic prevalence and related health outcomes: A scoping review and synthesis. *International Journal of Drug Policy*. 1, 87-96. doi.org/10.1016/j.drugpo.2017.11.008

Sagar, K. A., Lambros, A. M., Dahlgren, M. K., Smith, R. T., & Gruber, S. A. (2018). Made from concentrate? A national web survey assessing dab use in the United States. *Drug and alcohol dependence*, *190*, 133-142. https://doi.org/10.1016/j.drugalcdep.2018.05.022

SAMHSA Office of Applied Studies (2009). National Survey on Drug Use and Health: Lifetime, past year, and past month illicit drug use, by selected age categories and gender. Retrieved Sep. 16, 2020, from http://www.oas.samhsa.gov/NSDUH/2K8NSDUH/tabs/INDEX.PDF

Stone, A. L., Becker, L. G., Huber, A. M., & Catalano, R. F. (2012). Review of risk and protective factors of substance use and problem use in emerging adulthood. *Addictive Behaviors*, 37(7), 747–775. doi: 10.1016/j.addbeh.2012.02.014

Ter Bogt, T. F., De Looze, M., Molcho, M., Godeau, E., Hublet, A., Kokkevi, A., ... & Pickett, W. (2014). Do societal wealth, family affluence and gender account for trends in adolescent cannabis use? A 30 country cross-national study. *Addiction*, *109*(2), 273-283.

Troutt, W. D., & DiDonato, M. D. (2017). Carbonyl compounds produced by vaporizing cannabis oil thinning agents. *The Journal of Alternative and Complementary Medicine*, *23*(11), 879-884. doi: 10.1089/acm.2016.0337

Van Bavel, J. J., Baicker, K., Boggio, P. S., Capraro, V., Cichocka, A., Cikara, M., ... & Willer, R. (2020). Using social and behavioural science to support COVID-19 pandemic response. *Nature human behaviour*, *4*(5), 460-471. https://doi.org/10.1038/s41562-020-0884-z

Van, D., McLaws, M. L., Crimmins, J., MacIntyre, C. R., & Seale, H. (2010). University life and pandemic influenza: Attitudes and intended behaviour of staff and students towards pandemic (H1N1) 2009. *BMC Public Health*, *10*(1), 1-9.

Vaughan, E. (2011). Contemporary perspectives on risk perceptions, health-protective behaviors, and control of emerging infectious diseases. *International journal of behavioral medicine*, *18*(2), 83. Doi. 10.1007/s12529-011-9160-y

Volkow, N. D., Baler, R. D., Compton, W. M., & Weiss, S. R. (2014). Adverse health effects of marijuana use. *New England Journal of Medicine*, *370*(23), 2219-2227. doi:10.1056/NEJMra1402309.

Watson, T. M., & Erickson, P. G. (2018). Cannabis legalization in Canada: How might 'strict' regulation impact youth? Drugs: Education, Prevention and Policy, 26(1), 1-5. doi:10.1080/09687637.2018.1482258

Chapter 2. Literature Review

This chapter provides a summary of the literature regarding various contexts in which cannabis consumption may change and factors that may influence consumption trends. Specifically, it discusses cannabis consumption behaviors of EA and their perceptions of cannabis consumption on health risks. The literature review also outlines perceived differences associated with gender-specific norms and behaviors of cannabis use. In addition, it highlights the potential impact of environmental and contextual factors on cannabis behaviors among vulnerable populations, specifically in relation to societal, and natural unprecedented factors and public health threats. This also includes the legislation transition of the *Cannabis Act* in Canada and its potential implications on cannabis consumption patterns among EA. The final section describes sex-specific biological variations in respiratory physiology and outlines the respiratory health risks associated with smoking or vaping cannabis.

2.1 Literature search strategy

The literature review was conducted by drawing upon conceptual frameworks, including the life course health development model (LCHD) (Halfon & Hochstein, 2002) and health belief model (HBM) (Rosenstock, 1994). Using these frameworks, themes related to the variables were considered which highlighted the interaction of broad environmental-level factors, including the cultural, social and political contexts that influence susceptibility to substance use, particularly cannabis consumption, and in relation to specific individual factors, including perceptions of harm, biological factors, and respiratory health outcomes.

2.2 Emerging Adulthood

2.2.1 Perceptions of cannabis use

The normalization of substances may be an aspect of societal transitions, which impact the age of onset of use, as well as the prevalence of use and the occurrence of any related health or societal problems (Bickel et al., 2014; Budney & Borodovsky, 2014). The use and presence of cannabis as a mainstream culture and normalized behavior, far preceded its current legislation status (Osborne & Fogel, 2016). Cannabis meets the multiple dimensions that outlines the changes associated with normalization of substance use, including its widespread availability and accessibility, trying rates, regular use, accommodation by non-using peers and overall cultural accommodation (Parker, 2005; Hathaway et al., 2018). These accommodations aligning with societal norms may also influence the perception of risk associated with implications of cannabis use. For example, theoretical models on health behavior, such as the HBM, suggest that individual beliefs about heath conditions predict health-related behaviors. Key factors include perceived severity (i.e. consequence) and susceptibility to a particular health-risk or outcome (Rosenstock, 1994). Perceived beliefs have often been considered in the implications of normalization as a consequence of the altering policy surrounding cannabis use, especially among youth (Sarvet et al., 2018). For example, permitting cannabis consumption for medicinal purposes may persuade young individuals to view cannabis as seemingly harmless, and as a self-medicating substance (Carliner et al., 2017; Sarvet et al., 2018).

The decreased perception in harm may pose deleterious health outcomes, including substance misuse and addiction, injury, and cognitive impairment, especially when use is frequent (i.e. nearly daily) (Sarvet et al., 2018). In fact, perceptions of low health risks or health benefits, high rates of peer use, social acceptance, and low motivation for change during the

period of emerging adulthood make EA disproportionately susceptible to health-compromising cannabis use (Stone et al., 2012). Indeed, the latter has been demonstrated among weekly cannabis smokers, which has been linked to adverse physiological changes in neuroanatomical structures in EA (18 to 25) (Iede et al., 2017).

Studies examining lived experiences of cannabis use among young individuals have found that the consequences of cannabis consumption are attributed to self-perceived beliefs based on elicited effects during personal experience or as expressed by their peers (McKiernan & Fleming, 2017). This suggests that EA may be likely to try cannabis before determining risks, and thus are open to experimenting. In addition, perceptions of cannabis use among EA is often regarded as an era of "Reefer Madness", in which the implications of use are exaggerated among users and their non-using peers (Mostaghim & Hathaway, 2013; Parnes et al., 2018). In one study of undergraduate students, users and non-users shared views regarding problematic use and often termed these individuals as "pot heads" (Mostaghim & Hathaway, 2013). Most respondents expressed that adverse effects and problematic use were evident if cannabis affected daily responsibilities or used for coping (Mostaghim & Hathaway, 2013; Hathaway et al., 2016). When compared to alcohol, respondents indicated that the quantity or frequency of cannabis use is not stringent upon known levels of excessive use, and using cannabis still allowed for getting stuff done (Hathaway et al., 2016). These perceptions make cannabis use problematic, as users may not be able to identify levels of consumption that may increase the risk of dependence or physiological harms.

Social influences on cannabis consumption

As the age cohort encompassing emerging adulthood is a population that generally composes the age of university and college students, it is essential to examine these trends

throughout the university culture experience (Hathaway et al., 2016; Mostaghim & Hathaway, 2013; Pearson et al., 2017). The university culture in particular, provides EA with multiple outlets and social networks of cannabis supply, which makes them more disposed to obtaining and experimenting with cannabis (Hathaway et al., 2018; Watson & Erickson, 2019). Factors such as moving out of the parental home and attending college have been indicated as proxies to increased substance use (Stone et al., 2012). Research shows that by graduation, approximately 47% of students have tried cannabis, and this rate is often influenced by peers who use, prior drug use, and low parental monitoring (Parnes et al., 2018). This is often correlated to exposure to parties where an opportunistic "puff" is common, and the freedom afforded by the university environment for using cannabis whether they were current or never users (Mostaghim & Hathaway, 2013). Indeed, evidence shows that students living on campus have higher odds of cannabis use than those living off-campus (even without family) (Kolar et al., 2018).

Peer use is particularly influential and reduces the likelihood that EA will remain abstinent. For example, the presence of fellow initiators among the social network of EA during the first year of college is predictive of experimenting with cannabis vaping (Cassidy et al., 2018). On the other hand, in comparison to students with no abstainers in their network, those with a majority or all of their peer network abstaining from cannabis were significantly more likely to be predicted nonusers (Kolar et al., 2018). Non-users' attitude may still reflect longstanding cultural assumptions about substance use as a deviant behavior, which may be correlated to cultural, familial and gendered expectations that discourage use of cannabis (Hathaway et al., 2016).

2.3 Gender and sex-specific differences

2.3.1 Cannabis consumption trends

Traditional gender norms are considered to be embedded in and constitutive of social structure, with implications for health behaviors (Short & Mollborn, 2015). In relation to substance use, socially constructed traditional norms may explain why males are three times more likely to use recreational substances (Crocker & Tibbo, 2017). For example, females have traditionally and historically experienced more social stigma and discrimination correlated to substance use than males (Greaves & Hemsing, 2020). In fact, a qualitative study that examined attitudes of cannabis use among undergraduate students suggests that longstanding cultural assumptions that associate cannabis use with women as deviating from female gender norms may still exist (Hathaway et al., 2016).

Furthermore, past and existing gender differences in cannabis use may reflect female's perceptions of risks associated with regular use (Pacek et al., 2015) and experiences with fear of severe stigma associated with substance use (Kolar et al., 2018). For example, Kolar et al. (2018) found that among undergraduate students across Canada - prior to regulatory changes in policy - females had lower odds of favorable attitudes in comparison to males towards cannabis acceptability (Kolar et al., 2018). In addition, this study suggested that gender is not a significant predictor of lifetime cannabis prevalence, although females were less likely to report recent consumption (Kolar et al., 2018). Indeed, recent evidence following the implementation of legalization in Canada shows that the prevalence of cannabis use continues to be higher among males (20.3%) than females (13.4%) among the household population aged 15 or older (Rotermann, 2020).

Similarly, a large cross-sectional study by Cuttler et al. (2016) found that males report higher rates of smoking and vaping cannabis than females. Detailed insights in relation to various methods of consumption explored in this study show that males were more likely than females to report primarily smoking joints/blunts and using concentrates and vaporizers, whereas females were more likely than males to report primarily using pipes and oral methods of administration (edibles, tinctures, capsules). The authors suggest that this gender difference in use may be the complexity associated with preparing certain modes of use. For example, joints/blunts and some concentrates, require more skill to prepare, while pipes and oral ingestion are easier and discrete methods. As such, gender differences in methods of administration may reflect female's tendency to be less experienced and/or discrete about their cannabis use (Cuttler et al., 2016; Greaves & Hemsing, 2020).

Evidence also suggests that preferences for specific methods of use, and quantity of smoked or vaped cannabis may be linked to subjective effects, such as greater cannabinoid sensitivity among females (Spindle et al., 2019). For example, an experiment by Matheson et al. (2020) found that there were differences in the smoking patterns of males and females, such that females needed to smoke less of a cannabis cigarette (i.e. joint), for the same duration, to achieve similar subjective effects. In this case, it was suggested that females may need to take smaller puffs and inhale less deeply and expose the lungs to smoke for a shorter duration. These findings may hold implications for gendered and sex-specific based consumption in relation to respiratory outcomes. There is a need for further research that examines specific patterns (i.e., frequency and quantity) and effects of various forms of cannabis in relation to sex and gender-based factors.

2.3.2 Respiratory Health

The respiratory system is the main source of exposure to toxins inhaled from smoking and vaping. Gender and sex play complex and interacting roles in the variations of health and disease risk among males and females (Rebuli, 2021). Expected social roles, perceived health and risk behaviors correlated to gender-specific differences, together with biological sex characteristics and mechanisms that differentiate males and females by anatomical and hormonal factors, influence lung physiology and epidemiology of respiratory diseases (Groeneveld et al., 2020). Differences in sex-specific anatomical characteristics of the respiratory system are seen throughout the whole lifespan (LoMauro & Alverti, 2018). For example, airways and lung dimensions are significantly different between males and females. During maturation from childhood into adolescence, male lung growth exceeds female lung size. In adulthood, regardless of similar age and height, males have larger lungs than females and larger conducting airways (Carey et al., 2007). Overall, differences in sex hormones and anatomical differences can have major impacts on respiratory health and may predispose a specific sex to certain lung diseases, although the research is nascent and key knowledge gaps exist (Carey et al., 2007; Rebuli, 2021).

Changes to the respiratory system induced by smoking tobacco can cause damage throughout the respiratory tract as the smoke becomes deeply embedded, moving from the upper airways to the alveoli (Behr & Nowak, 2002). Over time, the toxins from the smoke consisting of soluble gases and carcinogenic particles that are adsorbed and deposited into the airways and alveoli can increase the risk of respiratory complications (Behr & Nowak, 2002). Research examining the outcomes of tobacco smoking on respiratory health have suggested that females appear to have more severe COPD with early-onset disease (<60 yr) and a greater susceptibility to COPD with lower tobacco exposure (Barnes, 2016). Among youth (13-18), females tend to be more vulnerable to the impact of smoking tobacco on lung function (Langhammer et al., 2003).

Although there remains limited data on the effects of cannabis smoking among EA and sex-specific effects on respiratory health, these outcomes may predict similar outcomes in cannabis users, and are important to examine in light of the legislation change in Canada.

2.4 Influential Environmental and Contextual Factors

2.4.1 Legalization of cannabis and influence on consumption

Societal norms pertaining to the permissible use of substances and related penalties tend to shift overtime (Crépault, 2019). Accordingly, the perceived shift in determining the permissibility of substance use is embedded in changing cultural and historical contexts and is considered a long-term social process (Klaue, 1999). This gradual shift can also lend similarly to what has been experienced with cannabis in Canada. With limited understanding of individual-level effects, cannabis retained the status of a social problem with its use deserving severe penalty under federal criminal law in 1923 (Hathaway & Erickson, 2003). Any cannabis issues remained dormant until the rapid rise of the 1960s counterculture generation driven by young consumers in the era of "sex, drugs, and rock 'n' roll ethos" (Crépault, 2019; Hathaway & Erickson, 2003). This would later entail many decades of deliberation suggesting reform of the strict prohibitionist stance. The historical pathway consisted of political, cultural, and social factors that led to the reform we see today – from becoming a widely used medicinal product, to a common feature of leisure, and largely normalized in the public's eyes (Hathaway & Erickson, 2003; Hathaway et al., 2016; Osborne & Fogel, 2016). The trajectory of cannabis consumption and influence in Canada is a story of a political process that spanned decades, and why once historically recognized as a "4/20" celebration (i.e., cultural slang for day of cannabis consumption), became another controlled psychoactive substance of the state on October 17,

2018. The *Cannabis Act* was implemented in consideration with many key factors and public aims.

Specifically, Bill C-45 the *Cannabis Act* aims:

> "To prevent young persons from accessing cannabis, to protect public health and public safety by establishing strict product safety and product quality requirements and to deter criminal activity by imposing serious criminal penalties for those operating outside the legal framework. The Act is also intended to reduce the burden on the criminal justice system in relation to cannabis" ("An Act respecting cannabis and to amend the Controlled Drugs and Substances Act, the Criminal Code and other Acts", 2018).

While it has been viewed at various times as a "deviant" subculture, legalization of recreational use has been argued to have positive effect in optimizing public health, supplementing therapeutic use, producing an economic advantage, and in reducing crime rates (Hathaway & Erickson, 2003; Osborne & Fogel, 2016). Considering that the previous dominant policy model was ineffective in curtailing consumption (Fischer et al., 2017), there is reason to believe that legalization may lead to consumption increase, due to ease of accessibility, perceived notion of safety, and product diversification (Parnes et al., 2018; Watson & Erickson, 2019). Equally, it allows for easier exploration of risk behaviors, and developing lower risk consumption guidelines (Fischer et al., 2017). Although, the harms may precede public health improvements, especially for vulnerable subpopulations. Indeed, the consumption of cannabis has increased over the last few decades partly due to low perceived risks of smoking cannabis in adolescents and young adults (Carliner et al., 2017; Brooks-Russel et al., 2018; Sarvet et al., 2018). According to the Canadian Tobacco, Alcohol and Drugs Survey (CTADS) in 2015, the prevalence of past-year cannabis consumption was 28.4% among 18 to 24-year-olds, which was

higher than among other age groups (17.5% at ages 15 to 17; 17.7% at ages 25 to 44; 7.0% at ages 45 to 64; and 1.6% at age 65 or older) (Rotermann & Macdonald, 2018). Recent estimates show that the prevalence of use remains highest among 18 to 24-year-old individuals and has since increased to 33.3% (Rotermann, 2019).

In reflection of cannabis-related policies in other parts of the world, Canadian researchers predicted that the legalization of recreational cannabis in Canada would have similar overarching influence on consumption (Windle, 2019). For example, research based in the USA examining the prevalence of cannabis use patterns before and after legalization across various jurisdictions including Oregon and Colorado, suggest that the policy change surrounding the recreational legalization of cannabis use is a contributing factor related to increased rates of cannabis consumption among undergraduate students (Kerr et al., 2017; Parnes et al., 2018). Specifically, Parnes et al. (2018) found that following recreational legalization in Colorado, rates of trying cannabis increased almost 11% (from 43.5% to 53.6%) (p <0.001). This increase was higher among students over 21 years (the legal age of possession), from 40.4% to 60.9% (p < .001) (Parnes et al., 2018). Similarly, recent national estimates from Canada predicted increases in cannabis consumption; the prevalence of Canadians 15 years and older reporting use increased from 14.9% (4.5 million) in 2018 (before legalization) to more than 16.8% or 5.1 million people by 2019 (Rotermann, 2020). Accordingly, trends towards an incline in cannabis consumption is predicted to likely continue as resources to access spread, social tolerance increases and perceptions of harm decrease (Budney & Borodovsky, 2017; Parnes et al., 2018).

2.4.2 Vaping and health risks

Vaping cannabis products, as an alternative to smoking or in addition to smoking (dual use), has become a prevalent mode of cannabis consumption following the legalization of

cannabis and the rise of portable EVD (Fataar & Hammond, 2019; Budney et al., 2015; Lee et al., 2016). This is especially relevant among young users between 18 and 25 years of age (Cassidy et al., 2018; Lankenau et al., 2017). In fact, recent studies have shown that at least 7 to 29% of college students have used EVD for cannabis (Cassidy et al., 2018; Frohe et al., 2017; Jones et al., 2016; Kenne et al., 2017). The popularity of vaping among young adults may be related to a number of reasons, such as the discreetness of the vapor, addition of flavors that are incorporated into the vaping liquids, the versatility of devices, and the rapid onset of desirable effects (Abrams et al., 2007; Cassidy et al., 2018; Malouff et al., 2014).

Vaporizers, particularly e-cigarettes, as a mode of nicotine consumption emerged in 2003, with basic designs that resembled conventional cigarettes in shape (Bhatnagar et al., 2014; King et al., 2020). Second and third generation devices, with more appealing designs, facilitation of flavors and other substances (THC) (Bhatnagar et al., 2014), influenced popularity across North America between 2017 and 2018 (Fataar & Hammond, 2019). In 2018, the FDA Commissioner declared that electronic devices used for cannabis and nicotine liquid products among youth had reached “nothing short of an epidemic proportion of growth” (Printz, 2018). In addition, the rapid evolution of these products complicates assessment of product risks, and the ability to assess specific causes of health risks, thus impeding harm reduction guidelines (Bhatnagar et al., 2014).

The great appeal for vaping and presumption of vaping as a safer alternative to smoking, may have led to unknown lung-related illnesses (Chand et al., 2020). In fact, in November 2019, the CDC declared an “outbreak” of the ‘e-cigarette or vaping product use associated lung injury’ also known as 'EVALI'. In the USA, 70% of cases reported were young men (Perinne et al., 2019), highlighting that gender-based cannabis consumption behaviors may shape health risks.

In addition, this epidemic has been largely associated with purchasing products from informal sources (King et al., 2020), suggesting that males may be more likely to access counterfeit products, although the cause of EVALI are likely to be multifactorial (Kazachkov & Pirzada, 2020). Although the specific cause of vaping-related lung injuries remains unclear, many of those affected used cannabis oil via a vape pen containing a significant amount of vitamin E acetate in the vape liquid (King et al., 2020; Troutt & DiDonato, 2017). It has been speculated that THC based products and vitamin E acetate may act synergistically in the cause of illnesses (Evans et al., 2021).

EVALI

In Canada, as of August 14, 2020, 20 cases of vaping-associated lung illness have been reported, with THC and nicotine products (Government of Canada, 2020). The incidents of lung injury associated vaping in the USA have surmounted the numbers in Canada, with more than 2800 cases and 68 deaths. Overall, young adults are the most affected population (Aberegg et al., 2020; King et al., 2020). EVALI cases are characterized as a flu-like illness, with presentation of various systemic and respiratory symptoms, such as fever, chills, vomiting, shortness of breath, cough, chest pain, or abdominal pain (Hassoun et al., 2021). However, the evolving cases of EVALI and heterogenous pathology has led to misclassification and limited ability to reach a conclusive diagnostic. Diagnosing EVALI through computer tomography of the chest is often challenging because of undistinguishable radiological characteristics with other disease processes, particularly viral lung infections (Kazachkov & Pirzada, 2020). As of 2020, with the emergence of COVID-19 that can be associated with respiratory failure, a new requirement of a negative SARS-CoV-2 test began for making a diagnosis of EVALI (Blagev & Lanspa, 2020). Indeed, COVID-19 has made the independent diagnostic of EVALI difficult due to the high rate

of SARS-CoV-2 diagnosis in e-cigarette users, which was found to be 5 times more likely among young adults (13-24 years old), whom were daily users (Gaiha et al., 2020). Higher infection rates in e-cigarette users may be correlated to the behaviors during use, such as sharing devices and repetitive touching of hand to mouth and face (Gaiha et al., 2020).

Consequently, given that EVALI is a risk-factor associated with increased likelihood of COVID-19 infection and overall respiratory illness, it is imperative to examine whether the informed knowledge regarding the implications of such health-risk behaviors, may influence perceived beliefs of cannabis vaping and smoking outcomes, and correspondingly, patterns of use. Such factors may predict higher susceptibility to health-risks associated with consumption among vulnerable populations (Gaiha et al., 2020). Theories of behavior change suggest that perceived susceptibility to health risk and perceived threat are likely to reduce the adverse health-risk behavior. For example, the HBM predicts that smokers who perceive themselves susceptible to a threat are more likely to engage in cessation efforts (Davis et al., 2015).

In relation to EVALI and the COVID-19 pandemic, such public health concerns and natural unprecedented factors may have substantial influence on patterns of substance use based on perceived respiratory health-risks to motivate reduction. Recent evidence suggests that, following the EVALI outbreak in the USA, declines in vaping products, specifically e-cigarette sales were observed (Kreslake et al., 2021). Kreslake et al. (2021), indicated that youth (15-24) awareness of EVALI was positively associated with perceived risks of lung injury (current users OR 1.59, $p=0.004$; non-users OR 2.11, $p<0.001$), belief that e-cigarettes were harmful (current users OR 1.66, $p=0.002$; non-users OR 1.67, $p<0.001$) and intentions to quit among current users (OR 2.02, $p=0.002$). Another study found that users between 18 and 35 years viewed e-cigarettes safer compared to those 50 years and older ($p <0.001$) (Patel et al., 2020). In addition, prior e-

cigarette users viewed e-cigarettes and THC oils or vitamin E acetate containing e-cigarettes as safer than traditional cigarettes (Patel et al., 2020). These findings suggest that EVALI may not have a strong influence on perceived risks associated with vaping, especially among youth. However, it is not known whether patterns of consumption have changed among vapers in relation to EVALI, and these studies did not assess the specific products vaped (e.g., nicotine or THC). Since THC based products have been widely associated with the EVALI outbreak, it is important to examine these changes among cannabis vapers and how it may influence consumption patterns based on perceived safety of combusted compared to vaporized cannabis products.

In the event of adverse and unprecedented threats (i.e., COVID-19 pandemic), cannabis use changes in consumption may have important implications for health risks and evidence for informing public health policy.

2.4.3 Pandemics

A pandemic is considered the most widespread state of a disease, driven by highly contagious viruses that cause serious illness or death among a high proportion of the global population (WHO, 2010). Pandemics recorded in history have been caused by the transmission of emerging and re-emerging viruses, such as the virus responsible for SARS, and the subtype of influenza A (i.e., Swine Influenza H1N1) (Vaughan, 2011). In the context of zoonotic-derived coronaviruses, three have been identified as the cause of large-scale disease outbreaks, beginning with SARS, which emerged in 2002, followed by Middle East Respiratory Syndrome (MERS) in 2012, and the novel Sars-Cov-2 (COVID-19), which was discovered in Wuhan, China during late 2019 (Sohrabi et al., 2020). However, unlike COVID-19, the former outbreaks have been maintained locally and have been limited over time. COVID-19 has presented as a formidable

agent posing a unique set of challenges, with higher transmission and reproductive rates compared with many other infectious diseases, and with currently limited curative options (Eaton & Kalichman, 2020; Sohrabi et al., 2020).

COVID-19 primarily targets the respiratory tract, using the human body's mucosal tissues including the nose, mouth, upper respiratory tract, and less frequently conjunctival mucosa (i.e., eyes) as a means of infection (Berlin et al., 2020). Specifically, angiotensin-converting enzyme II (ACE2) expressed in lung tissue, as well as oral and nasal mucosa, is the cell receptor of SARS-CoV2 and the main route for receptor-mediated entry of the coronavirus into the human host (Cui et al., 2019). Related illness is commonly characterized by symptoms of fever, cough, shortness of breath and fatigue, while in more severe cases, the infection can cause pneumonia, kidney failure, and even death (Cui et al., 2019). In Canada, as of May 15, 2021, recent epidemiological data shows that there have been approximately 1.32 M total cases (and counting), and over 24,000 deaths (Government of Canada, 2021). These rates are comparably much higher to the death prevalence associated with SARS and Swine Flu; which resulted in 44 and 428 deaths in Canada, respectively (Bowden, 2020).

In relation to the high death and infection rates, multiple probable avenues have been explored to examine increased risk-factors for transmission and severe infection. As a novel virus with no residual immunity from prior exposure (Cui et al., 2019), the evolving state of COVID-19 has enforced public health approaches to be heavily dependent on social and behavioral change strategies to reduce transmission and severity of related-illness (Eaton & Kalichman, 2020). While the focus of public health interventions has been geared towards maintaining a multitude of public behavioral changes that can influence the spread of infectious diseases, such as wearing face masks, social distancing and better hygiene practice (Van Bavel et

al., 2020), unintended public behavioral fluctuations, including changes in substance use are also critical to examine.

2.4.2 Impact of natural crisis on substance use

Worldwide unprecedented disasters and subsequent societal transitions have been known to have substantial implications on physical and mental health, and associated health-risk behaviors (Vaughan, 2011; Pfefferbaum & North, 2020). In the context of natural disasters and extreme, adverse social circumstances, substances may be used for a multitude of reasons. For example, individuals may use substances to cope with trauma and attenuate mental stress, or anxiety (Dubey et al., 2020; Ornell et al., 2020). However, a catastrophic cycle can emerge due to suffering withdrawal among individuals with mental health disorders (e.g., anxiety). In addition, substance use on mental health factors may be bidirectional, such that it may prove useful for mood improvement in the short-term, but exacerbate users' symptoms in the long term (Chan et al., 2017; Hines et al., 2020).

Indeed, aftermath consequences have been associated with increased and continuous substance use (Adams et al., 2006; Wu et al., 2008). Research regarding the impact of natural disasters and infectious disease outbreaks on substance use have implicated the effects to be detrimental among individuals with mental health disorders, substance use disorders, and health-care workers (Orui et al., 2017; Soule et al., 2020; Wu et al., 2008). For example, during the SARS 2003 outbreak, alcohol consumption was used as a coping mechanism, and alcohol use predicted alcohol abuse and dependence 3 years later among hospital workers (Wu et al., 2008). Similarly, sustained increase in substance use, including cigarettes, alcohol and cannabis was seen following the largest human-made disaster of September 11, 2001 among New York residents (Vlahov et al., 2004).

In relation to natural geographical disasters, a study was conducted that examined risk factors of alcohol use following the Japan triple disaster on March 11, 2011 (Orui et al., 2017). Specifically, the study examined which factors are likely to pose a higher risk for continued drinking behavior among newly-started drinkers. In this study out of 37,867 individuals who did not drink prior to the Japan triple disaster, 9.6% reported drinking in 2012, and 53.8% reported continued drinking in 2013. Newly-started drinking behavior and heavy drinking was greater among males, younger generations (20, 30, 39 years old), and higher education (university, graduated school vs high school) (Orui et al., 2017).

Recent studies in relation to the COVID-19 pandemic suggest various reasons for increased substance use such as disruptions in daily life, boredom, and loneliness (Soule et al., 2020; Vanderbruggen et al., 2020). Evidence suggests that certain populations are more vulnerable to increased use, including dependent substance users, young adults and females (Soule et al., 2020; Van Laar et al., 2020). For example, females may be more likely than males to report increasing their use due to mental health and stress-related factors (Van Laar et al., 2020). This is concerning as predictors of problematic cannabis use has been attributed to coping-oriented reasons in which users become dependent on resorting to such outlets during acute stressful events (i.e., negative life events) to achieve temporary pleasure (Dubey et al., 2020; Van der Pol et al., 2013). A study conducted in the USA involving e-cigarette users found that an increase in substance use was more likely among dependent users, and this persisted despite acknowledging health risks related to COVID-19 and being aware of their current respiratory symptoms, such as chest pain, lung pain and cough (Soule et al., 2020). Moreover, a recent study in Canada found that risk characteristics associated with reporting an increase in cannabis use was the age group 18 to 29 years old (OR: 2.61, 95%CI 1.32-5.17) (Imtiaz et al.,

2021). However, there is a need for further research that makes distinctions of which measures (i.e., quantity, frequency), methods and forms may evolve, as this may have different implications on health risks (e.g., susceptibility to respiratory illnesses, dependence) (Leos-Toro, 2019; Russel et al., 2018).

Moreover, regular cannabis smokers may be more vulnerable to EVALI and COVID-19 health-risks (Borgonhi et al., 2020), as regular cannabis smoking is associated with respiratory symptoms, and increased airway resistance, which can precede acute impairments to lung function (Ghasemeisfe et al., 2018; Ribeiro & Ind, 2018). In addition, cannabis users may be more likely to be vulnerable to immunosuppression given the suppressive effects of THC on immune function (Owen et al., 2014) and expectancy of greater risk of pneumonia incidence in cannabis users (Ribeiro & Ind, 2018).

On the other hand, research suggests that alternative methods of cannabis consumption can be useful as therapeutic agents for the treatment of COVID-19. Preliminary evidence suggests that mouth wash applications, nebulizers, and encapsulated extracts of the cannabis strain Cannabis Sativa can downregulate the expression of ACE2 (Wang et al., 2020). However, since the application of cannabis in this study relates to non-combustion methods, similar benefits cannot be generalized to other inhalational routes of cannabis consumption, such as vaping and/or smoking (Wang et al., 2020). Moreover, in light of recent findings that tobacco smoking increases ACE2 levels and exacerbates clinical outcomes of COVID-19 (Brake et al., 2020), the effects of smoking and/or vaping cannabis on respiratory health outcomes in response to infection related to COVID-19 should be carefully investigated. In addition, this is particularly significant, because many cannabis users are also tobacco users, which could compound the effects (Ribeiro & Ind, 2016).

The impact of COVID-19 on emerging adults

The COVID-19 pandemic has inflicted a myriad of health and social consequences, translating into a range of emotional challenges. It has forced humans to go against their inherent need for social communication and interactions, disturbing means of stability. For EA in particular – whom are already prone to worry about the present and future (Arnett et al., 2014) – the instability and uncertainties enforced by the pandemic may increase these feelings, negatively impacting personal and interpersonal functioning (Germani et al., 2020). Indeed, the pandemic and associated pandemic procedures, fear, and deviation from normal life, can induce or exacerbate mental health conditions as well as related behavioral-risks and health outcomes (Van Bavel et al., 2020).

Cannabis is widely used as an experimentational substance, a product of conformity, and social enhancement among youth (Leos-Toro et al., 2020; Stone et al., 2012). Alternatively, popular maladaptive reasons for cannabis use among EAs include resorting to cannabis as a self-treatment method of various medical and psychiatric symptoms (e.g., stress and anxiety) (Hyman, 2009; Maslowsky et al., 2014; Walsh et al., 2017). As EAs are turning to cannabis to self-treat various conditions, equally they may use it as maladaptive response to the pandemic and a resource of self-medication for ailments related to COVID-19. Accordingly, the outbreak of the novel coronavirus has raised concerns about the effects on high-risk and vulnerable populations, such as individuals with compromised respiratory health (Berlin et al., 2020), as well as young adults - many of whom have defied public health calls and continued with group gatherings (Miller, 2020). Current epidemiological findings report that individuals aged 20-29 represent 18.9% of COVID-19 cases in Canada ("COVID-19 daily epidemiology update", 2021).

Studies that have examined public responses to viral outbreaks suggest, perceived beliefs and risks of the pandemic and illness may vary based on time periods in its preliminary to mid stages and in correlation with number of infections; influencing attitudes, perceptions and subsequently protective behaviors (Su et al., 2020; Van et al., 2010). A consensus expressed is the importance of promoting effective health behaviors amongst vulnerable populations whom may easily be swayed by changing patterns of infection over time, equally fluctuating risk perception.

Over the course of a pandemic, unmaintained precautionary behavior by the public, particularly young people participating in social activities, is likely to aggravate the spread of the virus and increase the burden on the health system (Van Bavel, 2020). For example, in 2009, the (once) novel influenza A (H1N1) pandemic that was associated with severe cases of pneumonia was prevalent among infections associated with younger populations (Van et al., 2010). This may be correlated to perceived risk associated with susceptibility to severe illness. For example, a study in Australia involving academic staff and students of a university found that the younger respondents (20-34) were the least likely group to believe that they were susceptible to infection (H1N1) (43.7%, 930/2129, $p = 0.04$). Of concern was the high proportion of students who indicated that they would still attend University with symptoms (Van et al., 2010). This suggests that young people are more likely to engage in behavior that they may perceive as important, or to fulfil an intrinsic desire, despite putting themselves or others at risk. In addition, perceived severity of illness and considering the pandemic as serious was significantly associated with being female. Although behavior changes were specific to undertaking social-distancing, and ensuring hygiene practices in this study, it provides information on perceived health risks and

risk behaviors of EA in the context of a pandemic and possible reflection of sex-specific differences in health-risk behaviors (Van et al., 2010).

Literature suggest that deviations from normality (such as legalization or public health concerns) that negatively impact the daily lifestyles of people may have unintended consequences, such as increases in substance use, and may be a cause for public health concern in the long-term (Dubey et al., 2020). However, behavioral impacts of disasters, natural and extreme events on substance use among EA have been limited. In particular, studies on the influence of cannabis consumption behaviors among recreational users following and during natural disasters are scarce. In addition, recent changes in liberation of cannabis laws and increased accessibility in Canada provides more incentive for those of legal age to experiment with use when living through the hardships of a pandemic. Given the high representation of EA in COVID-19 cases in Canada and their increased risk of substance use, particularly cannabis use, age-specific research is important.

2.5 Cannabis and Respiratory Health

2.5.1 Forms and methods of cannabis

The cannabis plant is a complex substance, consisting of two major compounds that exert varying effects in the endocannabinoid system, which is widely spread throughout the brain and body (Atakan, 2012). THC is the main component of the substance which induces euphoric and analgesic effects (Biehl & Burnham, 2015; Gloss, 2015), but may also induce effects in the lungs. Some studies have indicated a change in lung function, specifically an acute bronchodilation effect which can be seen 2 to 3 hours after inhalation (Tetrault et al., 2007), and up to 6 hours after oral ingestion (Ribeiro & Ind, 2016). However, the active constituents of the

cannabis plant may even have partial agonist and antagonistic effects on the airways, which may be modulated by the various strains and concentrations of compounds (Ribeiro & Ind, 2018).

The main preparations of cannabis vary in THC content depending on the way it is created and the source of the plant, which can result in 8 times the increase in THC content (Atakan, 2012). This is cause for concern from the evidence related to changes in lung function from THC and the various methods used to smoke, vape, or ingest diverse forms. Forms of cannabis widely used include the traditional herb and leaves, hashish, oil, and butane solvents (i.e., 'dabs') (Gloss, 2015). These forms are used in various modes, devices, and apparatuses (e.g., bongs, dab rigs, vape pens). Accordingly, the respiratory health effects of cannabis use may be determined in part by how the substance is consumed (Ribeiro & Ind, 2018; Biehl & Burnham, 2015). Although there are various modes used to smoke cannabis, research comparing smoking-based effects of cannabis forms are limited, and have almost exclusively examined effects of the cannabis plant (Macleod, 2015; Russel et al., 2018). Different cannabis modes used for smoking involve using varying quantities of cannabis and produce varying levels of carcinogenic compounds (Ribeiro & Ind, 2018). For example, blunts (which contain approximately 1.5 times the amount of cannabis compared to joints, and 2.5 times compared to pipes) can increase the risk of absorbing higher levels of carbon-monoxide (CO), compared to smoking joints (Meier & Hatsukami, 2016; Russel et al., 2018). Although bongs are intended to reduce inhalation of combusted chemicals as the smoke becomes filtered through the water, the production of tar and CO are 3 to 7 times and 2 to 4 times higher compared to that produced when smoking joints, respectively (Russel et al., 2018).

There are qualitative similarities in produced tobacco and cannabis smoke, consisting of a large mixture of compounds including hydrocyanic acid, carbon monoxide, ammonia and

carcinogenic substances that induce oxidative stress and inflammation in the lungs (Iede et al., 2017). The risks of respiratory consequences from inhaling cannabis may differentiate by the inhalational maneuvers used by cannabis smokers (Aldington et al., 2007). The dynamics of smoking cannabis differs from smoking regular tobacco – using larger puffs, deeper inhalation and greater breath holding time – resulting in a greater deposition of toxic substances in the lungs (Aldington et al., 2007; Iede et al., 2017; Tashkin et al., 1991). Contrastingly, these maneuvers have also been postulated to influence the bronchodilation effects and greater forced vital capacity (FVC) seen in cannabis users during spirometry tests (Gates et al., 2014; Lee & Hancox, 2011; Martinasek et al., 2016). Although the evidence remains inconsistent regarding the effects of cannabis on lung function, the fact that many toxic compounds that are formed from tobacco smoke are similar to cannabis smoke, and that the impact of various cannabis forms, potency and methods are unknown, necessitates further understanding of the respiratory health risks associated with these mechanisms.

2.5.2 Effects of smoking cannabis on respiratory health

Three prospective observational studies (Hancox et al., 2015; Taylor et al., 2002; Taylor et al., 2000) and 4 cross-sectional studies (Aldington et al., 2007; Moore et al., 2005; Macleod et al., 2015; Morris et al., 2018) examined the association between cannabis smoking and respiratory symptoms including cough, sputum production, and wheezing. Studies that compared populations of cannabis smokers verses tobacco smokers have identified greater detrimental effects on respiratory function and symptoms in tobacco users and among users of both substances than cannabis only users (Macleod et al., 2015; Tan et al., 2009). Evidence also suggests increased incidence of respiratory symptoms and adverse effects on pulmonary function in cannabis smokers than non-smokers (Moore et al., 2005). However, the evidence is conflicting

in determining the association between cannabis only use and respiratory health risks (Aldington et a., 2007; Macleod et al., 2015; Moore et al., 2005; Tan et al., 2009; Taylor et al., 2000; Taylor et al., 2002). In addition, respiratory symptoms have been found to decrease to levels similar to nonusers among young adult frequent cannabis smokers (weekly on average over the previous year), who reduce or quit smoking cannabis, but persist in users that continued frequent use, indicating adverse changes in lung function (Hancox et al., 2015).

Multiple studies examined airway obstruction and the risk of Chronic Obstructive Pulmonary Disease (COPD), which is a condition often preceded by indications of respiratory symptoms (Macleod et al., 2015; Tan et al., 2009; Taylor et al., 2002). Common measures of lung function represented in studies examining effects of cannabis smoking (Ghasemiesfe et al., 2018; Macleod et al., 2015; Tan et al., 2009), are spirometry indices: Forced Expiratory Volume in 1 second (FEV1) (L), Forced Vital Capacity (FVC) (L); and ratio of FEV_1/FVC. The ratio of FEV_1/FVC (a ratio below 0.80 in children, and 0.70 in adults) is often used to indicate airway obstruction and risk of COPD (Cerveri et al., 2008).

Indications of a decline in pulmonary function have been seen in young cannabis-dependent users. For example, a longitudinal study by Taylor et al. (2000) examining a birth cohort from 3 to 21 years of age, determined that significant respiratory symptoms and airflow obstruction associated with smoking cannabis became apparent among young adults at 21 years old. Cannabis-dependent individuals used cannabis 230 times during the previous 12 months; 36% and 35% of cannabis-dependent non-tobacco smoking participants (n=28), and those who also smoked tobacco (n=91) respectively, showed early airflow obstruction at 21 years of age. These proportions were much higher than the proportion of non-smokers (20%) that had a low FEV_1/FVC ratio (less than 80%). A second study by Taylor et al. (2002) found a dose-dependent

relationship between a decline in pulmonary function (FEV_1/FVC) and cumultive cannabis exposure among participants that used cannabis on 900 or more occasions, at ages 18, 21, and 26. Compared to non-users, the mean FEV_1/FVC was 7.2%, 2.6% and 5.0% less than in users within the latter age groups, respectively. This suggests that even early stages of smoking, might affect the respiratory function of adolescents, which can translate into the period of emerging adulthood and when effects may become apparent.

Macleod et al. (2015) examined measures of cannabis use, and type of cannabis (resin or herbal) smoked in the form of joints among adults (above the age of 18 years) from the United Kingdom. Each additional joint-year (joint-year defined as one joint a day for 1 year) of cannabis use was associated with a 0.3% (95% CI 0.0, 0.5) increase in prevalence of COPD (defined as the presence of a post-bronchodilator per cent predicted FEV_1/FVC <0.70.). The prevalence of COPD among tobacco only smokers was 24.3%, but slightly higher (25.2%) among tobacco and cannabis smokers. In addition, the prevalence of COPD in the younger age cohort (15 to 24 years) was 8.3% (95% CI: 1.5 to 35.4).

A Canadian population-based study of 878 individuals aged 40 years and older, found a statistically significant interaction with tobacco smoking, such that smokers of both cannabis and tobacco had an increased risk of having COPD compared to non-smokers, after adjusted for confounders such as age, sex, and asthma (Tan et al., 2009). However, there was no association between exclusive cannabis smoking and COPD. Only four COPD patients were exclusive current cannabis smokers, limiting definite conclusions (Tan et al., 2009). Similarly, Moore et al. (2005) found that compared to nonusers, both cannabis and tobacco users had a higher proportion of individuals with an FEV_1/FVC ratio <70% (OR 2.56, 95% CI 1.54 to 4.35 and OR 6.25, 95% CI 4.76 to 8.33, respectively). When comparing dual users (cannabis and tobacco)

with tobacco-only users, dual users had greater odds of chronic bronchitis (OR, 2.10, 95% CI, 1.07 to 4.15; P=.03), coughing on most days (OR, 1.87, 95% CI, 1.24 to 2.83; P=.004), phlegm production (OR, 1.60, 95% CI, 1.02 to 2.50; P=.04), wheezing (OR, 2.38, 95% CI, 1.57 to 3.61; P=.0001), and chest sounds without a cold (OR, 1.90, 95% CI, 1.06 to 3.39; P=.03). In general, cannabis smokers showed increased rates of respiratory symptoms similar to those of tobacco smokers, compared to non-smokers (Moore et al., 2005).

Aldington et al. (2007) studied lung function in a convenience sample of 339 people (25 to 75 years old) in Wellington, New Zealand, who were either nonsmokers (n=81), smokers of either tobacco (n=92) or cannabis only (n=75), or smokers of both substances (n=91). Cannabis users were defined by a lifetime exposure of at least 5 joint-years. Chronic bronchitis, defined as daily sputum production for at least 3 months of the year for greater than 2 years duration was associated with cannabis use (OR 2.0, 95%CI 1.4 to 2.7). Overall, chest tightness was associated with cannabis smoking but not tobacco smoking. In addition, the presence of asthma diagnosed after the age of 16 years was associated with cannabis use (OR 1.7 (1.0 to 2.9) but not tobacco (OR 1.2 (0.7 to 1.9). However, wheeze and cough were assocaited with cannabis smoking, and tobacco smoking (Aldington et al., 2007). Notably, Aldington et al. (2007) also suggest that one joint of cannabis is similar to the effect of 2.5-5 tobacco cigarettes on airflow obstruction, with evidence suggesting a reduction in $FEV_{1.}$

Studies examining the effects of cannabis on pulmonary function on each individual measure, including the predicted percent of FEV_1 and FVC have seen an increase in FVC, leading to a reduced FEV_1/FVC ratio, whereas smoking tobacco is largely associated with an irreversible decrease in FEV_1 (Ribeiro & Ind, 2018; Kempker et al., 2015; Pletcher et al., 2012). This increase in FVC has been linked to the possible bronchodilator effects of THC and deeper

inhalation technique used by cannabis smokers (Ribiero & Ind, 2016). Differences in determination of COPD risk measures have made it challenging to delineate the effects of cannabis smoking on respiratory health, which may differentiate from tobacco smoking.

For example, a study by Kempker et al. (2015), found that with heavy use (over 20 joint years), the odds of a FEV_1/FVC less than 70% increased two-fold, although this was a result of an increase in FVC, rather than a disproportional decrease in FEV_1. Similarly, Morris et al. (2018) found that, a history of 10 or greater joint years among 40 to 80-year-old cannabis users, was associated with a significantly higher FVC, when compared to nonusers (i.e., zero joint years). This study suggests that, if FEV_1 is held constant than a higher FVC would result in a lower FEV_1/FVC ratio, indicating mild obstruction, as found in previous studies (Kempker et al., 2015; Pletcher et al., 2012). In addition, higher joint years was associated with more chronic bronchitis symptoms (e.g., wheeze). Although, this study was not able to determine if long-term heavy cannabis smoking in the absence of tobacco smoking is associated with lung symptoms or airflow obstruction, particularly in those who have never smoked tobacco cigarettes.

Furthermore, research examining the sex-specific differences in relation to respiratory health outcomes linked to cannabis use have found negligible differences (Hancox et al., 2010). These results may be due to limited sample size, insufficient data, and influence of stigma related to the previous legislation. For example, a longitudinal study by Hancox et al. (2010) examining cannabis use at ages 18, 21, 26 and 32 years, found an association between cannabis smoking based on the number of joint years and evidence of hyperinflation and increased large airway resistance. This was of borderline significance after adjusting for tobacco use. Analyses of sex–cannabis and sex–tobacco smoking interaction terms found no evidence that the effect of smoking either substance was different for males and females for any of the outcomes (Hancox

et al., 2010). Nonetheless, there is limited evidence for sex-specific effects on respiratory health. Differences in relation to predisposition to respiratory diseases based on sex characteristics, increasing cannabis consumption and various forms and methods requires further research to elucidate these implications.

2.5.3 Effects of vaping cannabis on respiratory health

The lack of evidence on the health effects of chronic vaping and unknown long-term health effects thus far has indirectly persuaded perceptions of vaping as a safer and more advantageous way to consume cannabis (Budney et al., 2015; Etter, 2015). Vaping is perceived to eliminate some of the potentially harmful (carcinogenic) byproducts of cannabis smoke (i.e. benzene, toluene) produced during combustion methods (e.g., joint, bong) (Etter, 2015; Earleywine & Barnwell, 2007; Pomahacova et al., 2009). For example, the desktop-based Volcano vaporizer – "a vaporizer or evaporator that can evaporate the active substances or aromas from plant material by using a hot air flow" - has demonstrated a reduction in expired carbon monoxide (CO) levels then after smoking cannabis (Abrams et al., 2007; Hazekamp et al., 2006; Pomahacova et al., 2009). However, there are now many devices sold popularly in the market, which can vary in their levels of delivery of toxicants into the lungs and into the air, depending on the material from which they are constructed (e.g. plastic, metal, glass) and their heating capacity (Budney et al., 2015).

Some literature on the effects of vaping cannabis on respiratory health has found fewer reports of self-reported respiratory symptoms compared to smoking cannabis (Earleywine & Barnwell, 2007; Earleywine & Van Dam, 2010). Based on the findings from Earleywine & Barnwell (2007), healthy individuals above the age of 18 years that used cannabis at least once in the previous month, and that reported vaporizing as their primary method for cannabis use

(2.2%; 152/6,883) were significantly less likely to report respiratory symptoms than participants who primarily used other methods (blunts, joints, water pipes, pipes). Specifically, compared to users using combustion methods, of which 56% (3767/6731) reported no respiratory symtoms, those who primarily used vaporizers were significantly more likely not to report symptoms (62%). However, increased respiratory symptoms were found to covary with the amount of cannabis consumption (based on 1-gram joint equivalents consumed per week), suggesting that a vaporizer may have more impact on respiratory symptoms in those who use more cannabis. An intervention study conducted by Earleywine & Van Dam (2010) provided a vaporiser to four regular cannabis users (between the ages of 22-38) with varying years of consumption (minimum 5 years of consumption) who had respiratory problems, for a period of one month. The researchers found that users had more appeal for using (strictly) the vaporizer, post-intervention. In addition, the cannabis users that used a vaporizer for a month instead of smoking, had improvements in respiratory symptoms. Percent change of improvements in six respiratory symptoms reported on a scale from 0 (not at all) to 9 (very much) were more evident among users that also smoked cigarettes (dropping 83% and 66%), compared to cannabis only smokers (dropping 50% and 25%) (Earleywine & Van Dam, 2010).

Contrastingly, a recent observational study that examined associations of nicotine and cannabis vaping found increased risk of bronchitis symptoms, wheeze, and shortness of breath in young adults (Mean age: 19.3 years (0.79) that vaped cannabis (Braymiller et al., 2020). Symptoms were associated with increasing frequency. When compared to those that had never vaped cannabis, increasing frequency (lifetime but not in the past 6 months, past 6 months but not in the past 30 days, 1 to 2 days in the past 30 days, and more than 3 days in the past 30 days) of vaping cannabis was associated with increased odds of reporting any bronchitis symptoms

(adjusting for nicotine vaping, sociodemographic, cigarette smoking and combustible cannabis use). Those that had vaped cannabis on 3 or more days in the past 30 days had increased odds of wheezing/whistling in the chest during the past 12 months. The authors suggest that prospective research that examines respiratory outcomes among exclusive nicotine and exclusive cannabis vapers are needed (Braymiller et al., 2020).

These studies suggest that although vaping may represent a harm reduction approach to short-term improvements in lung function, this does not mitigate vaping-attributable harms on respiratory health in the long-term and with increasing frequency. In addition, while some research suggests that the vaporizer may prove to be beneficial to improving respiratory symptoms among heavy and long-term cannabis smokers that switch to vaping exclusively (Earleywine & Van Dam, 2010), it may increase the risk of respiratory symptoms among young consumers initiating vaping of cannabis products.

2.6 Summary and Conclusions

Overall, literature suggests that cannabis smoking increases the risk of adverse respiratory health outcomes. Cumulative and frequent smoking is associated with respiratory symptoms, including cough, sputum or phlegm production and wheezing (Ghasemeisfe et al., 2018). However, there has been a paucity of studies examining the association between various measures of cannabis consumption in relation to quantity, frequency, mode, and forms of cannabis. In addition, recent political developments that have increased access to various products among vulnerable populations such as EA requires further monitoring of cannabis use trends. The increasing trend of dual use (smoking and vaping) necessitates research to examine the compounded effects of these methods of consumption (Fataar & Hammond, 2019; Lee et al., 2016).

There is also limited research particularly in Canada that examines trends overtime and specifically focuses on the rising young cohort of cannabis users (Leos-Toro et al., 2019). Specifically, there is scarce research examining the effects of cannabis consumption on respiratory health among at-risk populations that are more prone to experiment and use cannabis, such as EA. Furthermore, most of the data were largely collected prior to recent legislative changes; therefore, the relatively small percentage of heavy cannabis consumers examined may not reflect emerging trends in cannabis use (Ghasemiesfe et al., 2018).

EA may be vulnerable to health risks associated with a history of cannabis use (Iede et al., 2017; Taylor et al., 2002; Volkow et al., 2014), and susceptible to increased consumption following the federal policy change (Parnes et al., 2018; Windle et al., 2019). In addition, adverse social and public health consequences associated with the COVID-19 pandemic and EVALI may influence consumption patterns and increase the incidence of respiratory health risks. Considering that there are differences in social behaviors of cannabis use across gender and sex-specific physiological differences in lung function, it is imperative to understand the effects of various routes and varying measures of cannabis consumption on respiratory health in relation to gender and sex-specific differences among young cannabis users. Consequently, it is important that in this new legal environment, public health initiatives focus on educating safe consumption by developing a comprehensive understanding of harm-reduction guidelines.

References for Chapter 2

Aberegg, S. K., Cirulis, M. M., Maddock, S. D., Freeman, A., Keenan, L. M., Pirozzi, C. S., ... & Callahan, S. J. (2020). Clinical, Bronchoscopic, and Imaging Findings of e-Cigarette, or Vaping, Product Use–Associated Lung Injury Among Patients Treated at an Academic Medical Center. *JAMA Network Open*, *3*(11), e2019176-e2019176.

Abrams, D. I., Vizoso, H. P., Shade, S. B., Jay, C., Kelly, M. E., & Benowitz, N. L. (2007). Vaporization as a Smokeless Cannabis Delivery System: A Pilot Study. *Clinical Pharmacology & Therapeutics*, 82(5), 572–578. doi: 10.1038/sj.clpt.6100200

Ahmad, N., Flight, J., Singh, V. A., Poole, N., & Dell, C. A. (2008). Focus on gender-a national survey of Canadians' use of alcohol and other drugs Canadian Addiction Survey (CAS). *Ottawa (ON): Health Canada*.

An Act respecting cannabis and to amend the Controlled Drugs and Substances Act, the Criminal Code and other Acts, Cannabis Act (S.C. 2018, c.16). 2018. http://laws-lois.justice.gc.ca/eng/acts/C-24.5/page-1.html. Accessed 18 Sept 2020.

Arnett, J. J., Žukauskienė, R., & Sugimura, K. (2014). The new life stage of emerging adulthood at ages 18–29 years: implications for mental health. The Lancet Psychiatry, 1(7), 569–576. doi: 10.1016/s2215-0366(14)00080-7

Aldington, S., Williams, M., Nowitz, M., Weatherall, M., Pritchard, A., McNaughton, A., ... & Beasley, R. (2007). Effects of cannabis on pulmonary structure, function and symptoms. *Thorax*, *62*(12), 1058-1063.

Atakan, Z. (2012). Cannabis, a complex plant: different compounds and different effects on individuals. Therapeutic Advances in Psychopharmacology, 2(6), 241–254. doi: 10.1177/2045125312457586

Barnes, P. J. (2016). Sex Differences in Chronic Obstructive Pulmonary Disease Mechanisms. *American Journal of Respiratory and Critical Care Medicine*, 193(8), 813–814. doi: 10.1164/rccm.201512-2379ed

Behr, J., & Nowak, D. (2002). Tobacco smoke and respiratory disease. *World*, *58*(44), 1-20.

Berlin, I., Thomas, D., Le Faou, A. L., & Cornuz, J. (2020). COVID-19 and smoking. *Nicotine and Tobacco Research*, *22*(9), 1650-1652. doi:10.1093/ntr/ntaa059

Bhatnagar, A., Whitsel, L. P., Ribisl, K. M., Bullen, C., Chaloupka, F., Piano, M. R., ... & Benowitz, N. (2014). Electronic cigarettes: a policy statement from the American Heart Association. *Circulation*, *130*(16), 1418-1436.

Bickel, W. K., Johnson, M. W., Koffarnus, M. N., MacKillop, J., & Murphy, J. G. (2014). The

behavioral economics of substance use disorders: reinforcement pathologies and their repair. *Annual review of clinical psychology*, *10*, 641–677. https://doi.org/10.1146/annurev-clinpsy-032813-153724

Biehl, J. R., & Burnham, E. L. (2015). Cannabis Smoking in 2015: A Concern for Lung Health? [Review]. 1(3), 596-606.

Blagev, D. P., & Lanspa, M. J. (2020). Autopsy insights from the EVALI epidemic. *The Lancet. Respiratory medicine*, *8*(12), 1165–1166. https://doi.org/10.1016/S2213-2600(20)30327-1

Bloom, J. W., Kaltenborn, W. T., Paoletti, P., Camilli, A., & Lebowitz, M. D. (1987). Respiratory effects of non-tobacco cigarettes. Br Med J (Clin Res Ed), 295(6612), 1516-1518.

Borgonhi, E. M., Volpatto, V. L., Ornell, F., Rabelo-da-Ponte, F. D., & Kessler, F. H. P. (2021). Multiple clinical risks for cannabis users during the COVID-19 pandemic. *Addiction Science & Clinical Practice*, *16*(1), 1-4. https://doi.org/10.1186/s13722-021-00214-0

Bowden, O. (2020, February 4). Before coronavirus: How Canada tackled outbreaks in the past. Global News. Retrieved April 30, 2021. https://globalnews.ca/news/6504203/outbreaks-in-canada/

Brake, S. J., Barnsley, K., Lu, W., McAlinden, K. D., Eapen, M. S., & Sohal, S. S. (2020). Smoking upregulates angiotensin-converting enzyme-2 receptor: a potential adhesion site for novel coronavirus SARS-CoV-2 (Covid-19). doi: 10.1016/j.drugalcdep.2015.12.009

Braymiller, J. L., Barrington-Trimis, J. L., Leventhal, A. M., Islam, T., Kechter, A., Krueger, E. A., ... & McConnell, R. (2020). Assessment of Nicotine and Cannabis Vaping and Respiratory Symptoms in Young Adults. *JAMA network open*, *3*(12), e2030189-e2030189.

Budney, A. J., & Borodovsky, J. T. (2017). The potential impact of cannabis legalization on the development of cannabis use disorders. *Preventive medicine*, *104*, 31-36. doi: http://dx.doi.org/10.1016/j.ypmed.2017.06.034

Budney, A. J., Sargent, J. D., & Lee, D. C. (2015). Vaping cannabis (marijuana): parallel concerns to e-cigs? *Addiction*, 110(11), 1699–1704. doi: 10.1111/add.13036

Carey, M. A., Card, J. W., Voltz, J. W., Arbes Jr, S. J., Germolec, D. R., Korach, K. S., & Zeldin, D. C. (2007). It's all about sex: male-female differences in lung development and disease. *Trends in endocrinology and metabolism: TEM*, *18*(8), 308.

Carliner, H., Brown, Q. L., Sarvet, A. L., & Hasin, D. S. (2017). Cannabis use, attitudes, and legal status in the US: a review. *Preventive medicine*, *104*, 13-23. http://dx.doi.org/10.1016/j.ypmed.2017.07.008

Cassidy, R. N., Meisel, M. K., Diguiseppi, G., Balestrieri, S., & Barnett, N. P. (2018). Initiation

of vaporizing cannabis: Individual and social network predictors in a longitudinal study of young adults. *Drug and Alcohol Dependence*, 188, 334–340. doi: 10.1016/j.drugalcdep.2018.04.014

Cerveri, I., Corsico, A. G., Accordini, S., Niniano, R., Ansaldo, E., Antó, J. M., ... & de Marco, R. (2008). Underestimation of airflow obstruction among young adults using FEV1/FVC< 70% as a fixed cut-off: a longitudinal evaluation of clinical and functional outcomes. *Thorax*, *63*(12), 1040-1045.

Chand, H. S., Muthumalage, T., Maziak, W., & Rahman, I. (2020). Pulmonary Toxicity and the Pathophysiology of Electronic Cigarette, or Vaping Product, Use Associated Lung Injury. *Frontiers in pharmacology*, *10*, 1619. https://doi.org/10.3389/fphar.2019.01619

Crépault, J. (2019). Legalize It (But Don't Advertise It): The Public Health Case for Cannabis Legalization. *High Time*, 79-96.

Crépault, J. F., Rehm, J., & Fischer, B. (2016). The Cannabis Policy Framework by the Centre for Addiction and Mental Health: a proposal for a public health approach to cannabis policy in Canada. *International journal on drug policy*, *34*, 1-4. http://dx.doi.org/10.1016/j.drugpo.2016.04.013

Cui, J., Li, F., & Shi, Z. L. (2019). Origin and evolution of pathogenic coronaviruses. *Nature Reviews Microbiology*, *17*(3), 181-192. https://doi.org/10.1038/s41579-018-0118-9

Crocker, C. E., & Tibbo, P. G. (2018). The interaction of gender and cannabis in early phase psychosis. *Schizophrenia research*, *194*, 18-25. http://dx.doi.org/10.1016/j.schres.2017.04.046

Cuttler, C., Mischley, L. K., & Sexton, M. (2016). Sex Differences in Cannabis Use and Effects: A Cross-Sectional Survey of Cannabis Users. Cannabis and cannabinoid research, 1(1), 166–175. doi:10.1089/can.2016.0010

Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. *Health psychology review*, *9*(3), 323-344. DOI: 10.1080/17437199.2014.941722

Dubey, M. J., Ghosh, R., Chatterjee, S., Biswas, P., Chatterjee, S., & Dubey, S. (2020). COVID-19 and addiction. *Diabetes & metabolic syndrome*, *14*(5), 817–823. https://doi.org/10.1016/j.dsx.2020.06.008

Eaton, L. A., & Kalichman, S. C. (2020). Social and behavioral health responses to COVID-19: lessons learned from four decades of an HIV pandemic. *Journal of behavioral medicine*, *43*(3), 341-345. https://doi.org/10.1007/s10865-020-00157-y

Esterwood, E., & Saeed, S. A. (2020). Past Epidemics, Natural Disasters, COVID19, and Mental Health: Learning from History as we Deal with the Present and Prepare for the Future. *The Psychiatric quarterly*, *91*(4), 1121–1133. https://doi.org/10.1007/s11126-020-09808-4

Etter, J.F. (2015). Electronic Cigarettes and Cannabis: An Exploratory Study. European Addiction Research, 21(3), 124–130. doi: 10.1159/000369791

Evans, R. E., Herbert, S., Owen, W., & Rao, D. (2021). Case of e-cigarette or vaping product use-associated lung injury (EVALI) in London, UK. *BMJ Case Reports CP*, *14*(4), e240700. doi:10.1136/bcr-2020-240700

Fataar, F., & Hammond, D. (2019). The prevalence of vaping and smoking as modes of delivery for nicotine and cannabis among youth in Canada, England and the United States. *International journal of environmental research and public health*, *16*(21), 4111. doi:10.3390/ijerph16214111

Fischer, B., Russell, C., Sabioni, P., Van Den Brink, W., Le Foll, B., Hall, W., ... & Room, R. (2017). Lower-risk cannabis use guidelines: a comprehensive update of evidence and recommendations. *American journal of public health*, *107*(8), e1-e12.

Frohe, T., Leeman, R. F., Patock-Peckham, J., Ecker, A., Kraus, S., & Foster, D. W. (2018). Correlates of cannabis vape-pen use and knowledge among US college students. *Addictive behaviors reports*, *7*, 32-39. https://doi.org/10.1016/j.abrep.2017.11.004

Gaiha, S. M., Cheng, J., & Halpern-Felsher, B. (2020). Association between youth smoking, electronic cigarette use, and COVID-19. *Journal of adolescent health*, *67*(4), 519-523. https://doi.org/10.1016/j.jadohealth.2020.07.002

Gates, P., Jaffe, A., & Copeland, J. (2014). Cannabis smoking and respiratory health: consideration of the literature. *Respirology*, *19*(5), 655-662. doi: 10.1111/resp.12298

Germani, A., Buratta, L., Delvecchio, E., Gizzi, G., & Mazzeschi, C. (2020). Anxiety severity, perceived risk of COVID-19 and individual functioning in emerging adults facing the pandemic. *Frontiers in psychology*, *11*. doi: 10.3389/fpsyg.2020.567505

Ghasemiesfe, M., Ravi, D., Vali, M., Korenstein, D., Arjomandi, M., Frank, J., ... & Keyhani, S. (2018). Marijuana use, respiratory symptoms, and pulmonary function: a systematic review and meta-analysis. *Annals of internal medicine*, *169*(2), 106-115.

Gloss, D. (2015). An Overview of Products and Bias in Research. *Neurotherapeutics*, 12(4), 731–734. doi: 10.1007/s13311-015-0370-x

Government of Canada. (2021). *COVID-19 daily epidemiology update*, 15 May 2021.

Government of Canada 2021). *Vaping-associated lung illness*. From:

https://www.canada.ca/en/public-health/services/diseases/vaping-pulmonary-illness.html, Accessed date: 19 April 2021.

Greaves, L., & Hemsing, N. (2020). Sex and gender interactions on the use and impact of recreational cannabis. *International journal of environmental research and public health*, *17*(2), 509. doi:10.3390/ijerph17020509

Groeneveld, J. M., Ballering, A. V., van Boven, K., Akkermans, R. P., Olde Hartman, T. C., & Uijen, A. A. (2020). Sex differences in incidence of respiratory symptoms and management by general practitioners. *Family Practice*, *37*(5), 631-636.https://doi.org/10.1093/fampra/cmaa040

Hancox, R. J., Poulton, R., Ely, M., Welch, D., Taylor, D. R., McLachlan, C. R., ... & Sears, M. R. (2010). Effects of cannabis on lung function: a population-based cohort study. *European Respiratory Journal*, 35(1), 42-47. doi:10.1183/09031936.00065009

Hancox, R. J., Shin, H. H., Gray, A. R., Poulton, R., & Sears, M. R. (2015). Effects of quitting cannabis on respiratory symptoms. *European Respiratory Journal*, *46*(1), 80-87. doi: 10.1183/09031936.00034515

Hassoun, A., Brady, K., Arefi, R., Trifonova, I., & Tsirilakis, K. (2021). Vaping-associated lung injury during COVID-19 multisystem inflammatory syndrome outbreak. *The Journal of Emergency Medicine*, *60*(4), 524-530. https://doi.org/10.1016/j.jemermed.2020.12.005

Hathaway, A. D., & Erickson, P. G. (2003). Drug Reform Principles and Policy Debates: Harm Reduction Prospects for Cannabis in Canada. Journal of Drug Issues, 33(2), 465–495. doi: 10.1177/002204260303300209

Hathaway, A., Mostaghim, A., Kolar, K., Erickson, P. G., & Osborne, G. (2016). A nuanced view of normalisation: attitudes of cannabis non-users in a study of undergraduate students at three Canadian universities. *Drugs: Education, Prevention and Policy*, *23*(3), 238-246.doi: 10.3109/09687637.2015.1112362

Hathaway, A. D., Mostaghim, A., Erickson, P. G., Kolar, K., & Osborne, G. (2018). "It's Really No Big Deal": The Role of Social Supply Networks in Normalizing Use of Cannabis by Students at Canadian Universities. Deviant Behavior, 39(12), 1672–1680. doi: 10.1080/01639625.2017.1411047

Hines, L. A., Freeman, T. P., Gage, S. H., Zammit, S., Hickman, M., Cannon, M., ... & Heron, J. (2020). Association of high-potency cannabis use with mental health and substance use in adolescence. *JAMA psychiatry*, *77*(10), 1044-1051. doi:10.1001/jamapsychiatry.2020.1035

Hyman, S. M., & Sinha, R. (2009). Stress-related factors in cannabis use and misuse: implications for prevention and treatment. *Journal of substance abuse treatment*, *36*(4), 400-413. doi:10.1016/j.jsat.2008.08.005

Iede, M. A., Nunn, K., Milne, B., & Fitzgerald, D. A. (2017). The consequences of chronic cannabis smoking in vulnerable adolescents. Paediatric Respiratory Reviews,24, 44-53. doi:10.1016/j.prrv.2016.11.001

Imtiaz, S., Wells, S., Rehm, J., Hamilton, H. A., Nigatu, Y. T., Wickens, C. M., ... & Elton-Marshall, T. (2021). Cannabis Use During the COVID-19 Pandemic in Canada: A Repeated Cross-sectional Study. *Journal of Addiction Medicine*. doi: 10.1097/ADM.0000000000000798

Jones, C.B., Hill, M.L., Pardini, D.A., Meier, M.H. (2016). Prevalence and correlates of vaping cannabis in a sample of young adults. Psychol. Addict. Behav. 30, 915–921. https://doi.org/10.1037/adb0000217

Kazachkov, M., & Pirzada, M. (2020). Diagnosis of EVALI in the COVID-19 era. *The Lancet Respiratory Medicine*, *8*(12), 1169-1170.

Kempker, J. A., Honig, E. G., & Martin, G. S. (2015). The effects of marijuana exposure on expiratory airflow. A study of adults who participated in the US National Health and Nutrition Examination Study. *Annals of the American Thoracic Society*, *12*(2), 135-141. doi: 10.1513/AnnalsATS.201407-333OC

Kenne, D. R., Fischbein, R. L., Tan, A. S., & Banks, M. (2017). The use of substances other than nicotine in electronic cigarettes among college students. *Substance abuse: research and treatment*, *11*, 1178221817733736. https://doi.org/10.1177/1178221817733736

Kerr, D. C. R., Bae, H., Phibbs, S., & Kern, A. C. (2017). Changes in undergraduates' marijuana, heavy alcohol and cigarette use following legalization of recreational marijuana use in Oregon. Addiction, 112(11), 1992–2001. doi: 10.1111/add.13906

Kerridge, B. T., Pickering, R., Chou, P., Saha, T. D., & Hasin, D. S. (2018). DSM-5 cannabis use disorder in the National Epidemiologic Survey on Alcohol and Related Conditions-III: Gender-specific profiles. Addictive Behaviors, 76, 52–60. doi: 10.1016/j.addbeh.2017.07.012

King, B. A., Jones, C. M., Baldwin, G. T., & Briss, P. A. (2020). The EVALI and youth vaping epidemics—implications for public health. *New England Journal of Medicine*, *382*(8), 689-691. doi: 10.1056/NEJMp1916171

Klaue, K. (1999). Drugs, addiction, deviance and disease as social constructs. *Bulletin on Narcotics*, *51*(1/2).

Kolar, K., Erickson, P., Hathaway, A., & Osborne, G. (2018). Differentiating the Drug Normalization Framework: A Quantitative Assessment of Cannabis Use Patterns, Accessibility, and Acceptability Attitudes among University Undergraduates. *Substance Use & Misuse*, 53(14), 2339–2349. doi:10.1080/10826084.2018.1474226

Kreslake, J. M., Diaz, M. C., Shinaba, M., Vallone, D. M., & Hair, E. C. (2021). Youth and young adult risk perceptions and behaviours in response to an outbreak of e-cigarette/vaping-associated lung injury (EVALI) in the USA. *Tobacco Control*. http://dx.doi.org/10.1136/tobaccocontrol-2020-056090

Langhammer, A., Johnsen, R., Gulsvik, A., Holmen, T. L., & Bjermer, L. (2003). Sex differences in lung vulnerability to tobacco smoking. *European Respiratory Journal*, *21*(6), 1017-1023. doi: 10.1183/09031936.03.00053202

Lankenau, S. E., Fedorova, E. V., Reed, M., Schrager, S. M., Iverson, E., & Wong, C. F. (2017). Marijuana practices and patterns of use among young adult medical marijuana patients and non-patient marijuana users. Drug and Alcohol Dependence, 170, 181–188. doi:10.1016/j.drugalcdep.2016.10.025

Lee, D. C., Crosier, B. S., Borodovsky, J. T., Sargent, J. D., & Budney, A. J. (2016). Online survey characterizing vaporizer use among cannabis users. *Drug and alcohol dependence*, *159*, 227-233. doi: 10.1016/j.drugalcdep.2015.12.020.

Lee, M. H., & Hancox, R. J. (2011). Effects of smoking cannabis on lung function. *Expert review of respiratory medicine*, *5*(4), 537-547. https://doi.org/10.1586/ers.11.40

Leos-Toro, C., Fong, G. T., Meyer, S. B., & Hammond, D. (2020). Cannabis health knowledge and risk perceptions among Canadian youth and young adults. *Harm reduction journal*, *17*(1), 1-13. https://doi.org/10.1186/s12954-020-00397-w

LoMauro, A., & Aliverti, A. (2018). Sex differences in respiratory function. *Breathe (Sheffield, England)*, *14*(2), 131–140. https://doi.org/10.1183/20734735.000318

Macleod, J., Robertson, R., Copeland, L., McKenzie, J., Elton, R., & Reid, P. (2015). Cannabis, tobacco smoking, and lung function: a cross-sectional observational study in a general practice population. *British Journal of General Practice*, *65*(631), e89-e95. doi: 10.3399/bjgp15X683521

Malouff, J. M., Rooke, S. E., & Copeland, J. (2014). Experiences of Marijuana-Vaporizer Users. *Substance Abuse*, 35(2), 127-128. doi:10.1080/08897077.2013.823902

Martinasek, M. P., McGrogan, J. B., & Maysonet, A. (2016). A systematic review of the respiratory effects of inhalational marijuana. *Respiratory care*, *61*(11), 1543-1551. doi: 10.4187/respcare.04846

Maslowsky, J., & Ozer, E. J. (2014). Developmental trends in sleep duration in adolescence and young adulthood: evidence from a national United States sample. *Journal of Adolescent Health*, *54*(6), 691-697.

Matheson, J., Sproule, B., Di Ciano, P., Fares, A., Le Foll, B., Mann, R. E., & Brands, B. (2020).

Sex differences in the acute effects of smoked cannabis: evidence from a human laboratory study of young adults. *Psychopharmacology*, *237*(2), 305-316. doi: http://dx.doi.org/10.1007/s00213-019-05369-y

McKiernan A, Fleming K. Canadian youth perceptions on cannabis, Ottawa, ON: Canadian Centre on Substance Abuse. 2017. http://www.ccsa.ca/ Resource%20Library/CCSA-Canadian-Youth-Perceptions-on-Cannabis- Report-2017-en.pdf. Accessed 12 April 2021.

Meier, E., & Hatsukami, D. K. (2016). A review of the additive health risk of cannabis and tobacco co-use. *Drug and Alcohol Dependence*, *166*, 6-12. https://doi.org/10.1016/j.drugalcdep.2016.07.013

Miller, A. (2020, April 01). 'Everybody is susceptible': Why younger Canadians may be helping fuel the spread of COVID-19 | CBC News. Retrieved from https://www.cbc.ca/news/health/coronavirus-young-people-canada-1.5516936

Moore, B. A., Augustson, E. M., Moser, R. P., & Budney, A. J. (2005). Respiratory effects of marijuana and tobacco use in a US sample. *Journal of general internal medicine*, *20*(1), 33-37. doi: 10.1111/j.1525-1497.2004.40081.x

Morris, M. A., Jacobson, S. R., Kinney, G. L., Tashkin, D. P., Woodruff, P. G., Hoffman, E. A., ... & Bowler, R. P. (2018). Marijuana use associations with pulmonary symptoms and function in tobacco smokers enrolled in the Subpopulations and Intermediate Outcome Measures in COPD Study (SPIROMICS). *Chronic Obstructive Pulmonary Diseases: Journal of the COPD Foundation*, *5*(1), 46.

Mostaghim, A., & Hathaway, A. D. (2013). Identity formation, marijuana and "the self": A study of cannabis normalization among university students. *Frontiers in psychiatry*, *4*, 160. https://doi.org/10.3389/fpsyt.2013.00160

Orui, M., Ueda, Y., Suzuki, Y., Maeda, M., Ohira, T., Yabe, H., & Yasumura, S. (2017). The relationship between starting to drink and psychological distress, sleep disturbance after the Great East Japan Earthquake and nuclear disaster: the Fukushima Health Management Survey. *International journal of environmental research and public health*, *14*(10), 1281. doi:10.3390/ijerph14101281

Osborne, G. B., & Fogel, C. (2016). Perspectives on Cannabis Legalization Among Canadian Recreational Users. *Contemporary Drug Problems*, 44(1), 12–31. doi: 10.1177/0091450916670393

Owen, K. P., Sutter, M. E., & Albertson, T. E. (2014). Marijuana: respiratory tract effects. *Clinical reviews in allergy & immunology*, *46*(1), 65-81.

Pacek, L. R., Mauro, P. M., & Martins, S. S. (2015). Perceived risk of regular cannabis use in the United States from 2002 to 2012: differences by sex, age, and race/ethnicity. *Drug and alcohol dependence*, *149*, 232-244. https://doi.org/10.1016/j.drugalcdep.2015.02.009

Parker, H. (2005). "Normalization as Barometer: Recreational Drug Use and the Consumption of

Leisure by Young Britons." Addiction Research & Theory 13:205–15. doi:10.1080/16066350500053703

Parnes, J. E., Smith, J. K., & Conner, B. T. (2018). Reefer madness or much ado about nothing? Cannabis legalization outcomes among young adults in the United States. International Journal of Drug Policy, 56, 116–120. doi: 10.1016/j.drugpo.2018.03.011

Patel, T., Karle, E., Gubeladze, T., Pentecost, G., & Krvavac, A. (2020). Patient Perception of Vaping in the Midst of the Electronic Cigarette and Vaping Product Associated Lung Injury (EVALI) Epidemic. *Missouri medicine*, *117*(3), 265–270.

Pearson, M. R., Liese, B. S., Dvorak, R. D., & Marijuana Outcomes Study Team (2017). College student marijuana involvement: Perceptions, use, and consequences across 11 college campuses. *Addictive behaviors*, *66*, 83–89. https://doi.org/10.1016/j.addbeh.2016.10.019

Perrine, C.G.; Pickens, C.M.; Boehmer, T.K. Characteristics of a Multistate Outbreak of Lung Injury Associated with E-Cigarette Use, or Vaping—United States; Centre for Disease Control and Prevention: Atlanta, GA, USA, 2019.

Pfefferbaum, B., & North, C. S. (2020). Mental health and the Covid-19 pandemic. *New England Journal of Medicine*, *383*(6), 510-512. doi: 10.1056/NEJMp2008017

Pletcher, M. J., Vittinghoff, E., Kalhan, R., Richman, J., Safford, M., Sidney, S., … Kertesz, S. (2012). Association Between Marijuana Exposure and Pulmonary Function Over 20 Years. *Jama*, 307(2), 173. doi: 10.1001/jama.2011.1961

Pomahacova, B., Van der Kooy, F., & Verpoorte, R. (2009). Cannabis smoke condensate III: the cannabinoid content of vaporised Cannabis sativa. *Inhalation toxicology*, *21*(13), 1108-1112. doi: 10.3109/08958370902748559

Printz C. (2018). Food and drug administration takes steps to curb teen vaping. *Cancer* 124, 4431. 10.1002/cncr.31868

Rebuli M. E. (2021). Respiratory Sex Differences in Response to Smoke Exposure. *Sex-Based Differences in Lung Physiology*, 291–321. https://doi.org/10.1007/978-3-030-63549-7_10

Ribeiro, L. I., & Ind, P. W. (2016). Effect of cannabis smoking on lung function and respiratory symptoms: a structured literature review. *NPJ primary care respiratory medicine*, *26*(1), 1-8. doi:10.1038/npjpcrm.2016.71

Ribeiro, L., & Ind, P. W. (2018). Marijuana and the lung: hysteria or cause for concern? *Breathe*, 14(3), 196–205. doi: 10.1183/20734735.020418

Rosenstock, I. M., Strecher, V. J., & Becker, M. H. (1994). The health belief model and HIV risk behavior change. In *Preventing AIDS* (pp. 5-24). Springer, Boston, MA.

Rotermann, M. (2020). What has changed since cannabis was legalized. *Health Rep*, *31*(2), 11-20.

Rotermann, M. (2019). Analysis of trends in the prevalence of cannabis use and related metrics in Canada. *Health reports*, *30*(6), 3-13.

Rotermann, M., & Macdonald, R. (2018). Analysis of trends in the prevalence of cannabis use in Canada, 1985 to 2015. *Health reports*, 29(2), 10-20.

Russell, C., Rueda, S., Room, R., Tyndall, M., & Fischer, B. (2018). Routes of administration for cannabis use–basic prevalence and related health outcomes: A scoping review and synthesis. *International Journal of Drug Policy*, *52*, 87-96. https://doi.org/10.1016/j.drugpo.2017.11.008

Sarvet, A. L., Wall, M. M., Keyes, K. M., Cerdá, M., Schulenberg, J. E., O'Malley, P. M., ... & Hasin, D. S. (2018). Recent rapid decrease in adolescents' perception that marijuana is harmful, but no concurrent increase in use. *Drug and alcohol dependence*, *186*, 68-74. https://doi.org/10.1016/j.drugalcdep.2017.12.041

Short, S. E., & Mollborn, S. (2015). Social Determinants and Health Behaviors: Conceptual Frames and Empirical Advances. *Current opinion in psychology*, *5*, 78–84. https://doi.org/10.1016/j.copsyc.2015.05.002

Spindle, T.R.; Cone, E.J.; Schlienz, N.J.; Mitchell, J.M.; Bigelow, G.E.; Flegel, R.; Hayes, E.; Vandrey, R. Acute pharmacokinetic profile of smoked and vaporized cannabis in human blood and oral fluid. J. Anal. Toxicol. 2019, 43, 233–258.

Stone, A. L., Becker, L. G., Huber, A. M., & Catalano, R. F. (2012). Review of risk and protective factors of substance use and problem use in emerging adulthood. *Addictive Behaviors*, 37(7), 747–775. doi: 10.1016/j.addbeh.2012.02.014

Sohrabi, C., & Alsafi, Z. (2020). O Neill N, Khan M, Kerwan A, Al-Jabir A, Iosifidis C, Agha R. *World Health Organization declares global emergency: A review of the 2019 novel coronavirus (COVID-19). International Journal of Surgery*.

Soule, E. K., Mayne, S., Snipes, W., Guy, M. C., Breland, A., & Fagan, P. (2020). Impacts of COVID-19 on electronic cigarette purchasing, use and related behaviors. *International Journal of Environmental Research and Public Health*, *17*(18), 6762. doi:10.3390/ijerph17186762

Su, D., Chen, Y., He, K., Zhang, T., Tan, M., Zhang, Y., & Zhang, X. (2020). Influence of socio-ecological factors on COVID-19 risk: a cross-sectional study based on 178 countries/regions worldwide. *medRxiv : the preprint server for health sciences*, 2020.04.23.20077545. https://doi.org/10.1101/2020.04.23.20077545

Tan, W. C., Lo, C., Jong, A., Xing, L., Fitzgerald, M. J., Vollmer, W. M., Buist, S. A., Sin, D. D., & Vancouver Burden of Obstructive Lung Disease (BOLD) Research Group (2009). Marijuana and chronic obstructive lung disease: a population-based study. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne*, *180*(8), 814–820. https://doi.org/10.1503/cmaj.081040

Tashkin, D. P., Gliederer, F., Rose, J., Chang, P., Hui, K. K., Yu, J. L., & Wu, T. C. (1991). Effects of varying marijuana smoking profile on deposition of tar and absorption of CO and delta-9-THC. *Pharmacology Biochemistry and Behavior*, 40(3), 651-656. doi.org/10.1016/0091-3057(91)90377-E

Taylor, D. R., Poulton, R., Moffitt, T. E., Ramankutty, P., & Sears, M. R. (2000). The respiratory effects of cannabis dependence in young adults. *Addiction*, 95(11), 1669–1677. doi: 10.1046/j.1360-0443.2000.951116697.x

Taylor, D. R., Fergusson, D. M., Milne, B. J., Horwood, L. J., Moffitt, T. E., Sears, M. R., & Poulton, R. (2002). A longitudinal study of the effects of tobacco and cannabis exposure on lung function in young adults. Addiction, 97(8), 1055-1061.

Tetrault, J. M., Crothers, K., Moore, B. A., Mehra, R., Concato, J., & Fiellin, D. A. (2007). Effects of marijuana smoking on pulmonary function and respiratory complications: a systematic review. *Archives of internal medicine*, *167*(3), 221-228.

Troutt, W. D., & DiDonato, M. D. (2017). Carbonyl compounds produced by vaporizing cannabis oil thinning agents. *The Journal of Alternative and Complementary Medicine*, *23*(11), 879-884. doi: 10.1089/acm.2016.0337

Van, D., McLaws, M. L., Crimmins, J., MacIntyre, C. R., & Seale, H. (2010). University life and pandemic influenza: Attitudes and intended behaviour of staff and students towards pandemic (H1N1) 2009. *BMC Public Health*, *10*(1), 1-9.

Van Bavel, J. J., Baicker, K., Boggio, P. S., Capraro, V., Cichocka, A., Cikara, M., ... & Willer, R. (2020). Using social and behavioural science to support COVID-19 pandemic response. *Nature human behaviour*, *4*(5), 460-471. https://doi.org/10.1038/s41562-020-0884-z

Van Dam, N. T., & Earleywine, M. (2010). Pulmonary function in cannabis users: support for a clinical trial of the vaporizer. *International Journal of Drug Policy*, *21*(6), 511-513. doi:10.1016/j.drugpo.2010.04.001

Vanderbruggen, N., Matthys, F., Van Laere, S., Zeeuws, D., Santermans, L., Van den Ameele, S., & Crunelle, C. L. (2020). Self-reported alcohol, tobacco, and Cannabis use during COVID-19 lockdown measures: results from a web-based survey. *European Addiction Research*, *26*(6), 309-315. doi: 10.1159/000510822

Van Laar, M. W., Oomen, P. E., Van Miltenburg, C. J., Vercoulen, E., Freeman, T. P., & Hall, W. D. (2020). Cannabis and COVID-19: Reasons for Concern. *Frontiers in psychiatry*, *11*, 1419. doi: 10.3389/fpsyt.2020.601653

Vaughan, E. (2011). Contemporary perspectives on risk perceptions, health-protective behaviors, and control of emerging infectious diseases. *International journal of behavioral medicine*, *18*(2), 83. Doi. 10.1007/s12529-011-9160-y

Vlahov, D., Galea, S., Ahern, J., Resnick, H., & Kilpatrick, D. (2004). Sustained increased consumption of cigarettes, alcohol, and marijuana among Manhattan residents after september 11, 2001. *American journal of public health*, *94*(2), 253–254. https://doi.org/10.2105/ajph.94.2.253

Walsh, Z., Gonzalez, R., Crosby, K., Thiessen, M. S., Carroll, C., & Bonn-Miller, M. O. (2017). Medical cannabis and mental health: A guided systematic review. *Clinical psychology review*, *51*, 15-29. http://dx.doi.org/10.1016/j.cpr.2016.10.002

Windle, S. B., Wade, K., Filion, K. B., Kimmelman, J., Thombs, B. D., & Eisenberg, M. J. (2019). Potential harms from legalization of recreational cannabis use in Canada. *Canadian Journal of Public Health*, 110(2), 222–226. doi: 10.17269/s41997-018-00173-1

Wang, B., Kovalchuk, A., Li, D., Ilnytskyy, Y., Kovalchuk, I., & Kovalchuk, O. (2020). In Search of Preventative Strategies: Novel Anti-Inflammatory High-CBD Cannabis Sativa Extracts Modulate ACE2 Expression in COVID-19 Gateway Tissues. doi: 10.20944/preprints202004.0315.v1

Watson, T. W., & Erickson, P.G. (2019) Cannabis legalization in Canada: how might 'strict' regulation impact youth? Drugs: Education, Prevention and Policy, 26:1, 1-5, doi:10.1080/09687637.2018.1482258

World Health Organization. (2016). The health and social effects of nonmedical cannabis use. Geneva, Switzerland: World Health Organization [ISBN 978 92 4 151024 0] Retrieved from http://www.who.int/substance_abuse/publications/msb_cannabis_report.pdf?ua=1

World Health Organization. What is a pandemic? (2020, March 12). Retrieved from https://www.who.int/csr/disease/swineflu/frequently_asked_questions/pandemic/en/

Wu, P., Liu, X., Fang, Y., Fan, B., Fuller, C. J., Guan, Z., ... & Litvak, I. J. (2008). Alcohol abuse/dependence symptoms among hospital employees exposed to a SARS outbreak. *Alcohol & Alcoholism*, *43*(6), 706-712.

Chapter 3. Methodology

The current chapter describes the methodology used to conduct this research, guided by two theoretical frameworks, known as the Health Belief Model (Rosenstock, 1994) (Figure 3.1) and Life Course Health Development Framework (Figure 3.2) (Halfon & Hochstein, 2002). Specifically, this chapter consists of four sections. The first section describes the research design and the data collection tool administered to collect information from the study participants. The second section describes the content of the survey in relation to the variables of the conceptual frameworks, followed by a third section that describes participant recruitment. Finally, the chapter concludes with a description of the analysis plan in relation to each objective that led to the study results.

3.1 Research design and application of frameworks

This research used an exploratory, quantitative cross-sectional study design. Exploratory research is necessary when scholars "have little or no scientific knowledge about the group, process, activity, or situation they want to examine but nevertheless have reason to believe it contains elements worth discovering" (Stebbins, 2001, pg. 6). By observing natural occurrences and subsequent social changes, exploratory research enables the discovery of patterns and sequences of events that can lead to understanding the underlying principles and laws of behavior (Edgar et al., 2017).

The focus of this study was to examine cannabis consumption profiles (i.e. route of inhalation, form of cannabis, mode of use, consumption frequency, and quantity), and changes in cannabis consumption profiles influenced by policy amendments and public health concerns, including the legalization of recreational cannabis consumption in Canada (October 2018), the declaration of the EVALI epidemic (November 2019), and the COVID-19 pandemic (March

2020), among EA in Canada. The study also examined respiratory health status of cannabis users in relation to sex-specific differences and correlates related to cannabis exposure profiles.

This study involved the development of a survey guided by the LCHD framework and HBM. The LCHD framework outlines the interaction of various bio-behavioural determinants that influence health across the life-course (Halfon & Hochstein, 2002). In this framework, timed experiences, such as the impact of an exposure (i.e., onset of cannabis initiation) during a sensitive or critical period of development influences the multiple nested components that make up the macro contexts and micro contexts of health. In this study, the LCHD framework was applied to examine how the macro contexts of health, including the culture and policy environment, sociodemographic and genetic characteristics, as well as social environmental risk factors, interact with micro contexts of health and regulatory processes to predict respiratory health outcomes. The micro context includes the physiological aspects (i.e., health conditions) and behavioral systems in relation to cannabis consumption profiles which may affect people's respiratory health (Figure 3.1). Appendix E illustrates the components of the LCHD framework and the questions included in the survey.

Perceived health risks to a health outcome or condition related to a risk behavior, influences individuals to take action that positively benefit their health. In considering these factors, the HBM was also used to guide the development of the survey as an explanatory framework to examine salient correlates of change in cannabis frequency/quantity. Drawing from the HBM, questions were included in the survey to examine diverse structural and background components (e.g., cultural/policy environment, demographic characteristics) which may have an indirect effect on individual perceptions regarding cannabis consumption as a health risk behavior. For example, cannabis use is more prevalent among males than females (Greaves &

Hemsing, 2020), which may be influenced by the fact that females perceive greater harms for cannabis than males (Harris-Lane, 2020). In addition, males tend to perceive lower levels of risk of infection compared with females (Rodriguez-Besteiro et al., 2021), which may also indirectly influence cannabis patterns in the context of a pandemic. Accordingly, guided by the HBM, the survey aimed to collect data related to the main constructs of the model to examine predictors of change in relation to cannabis: background and demographic information, perceived risk/harm associated with cannabis consumption, perceived barriers that would impede in undertaking recommended behavior, and susceptibility to contracting a health condition (i.e., COVID-19) (Figure 3.2).

Survey administration tool

The survey was administered online through Google Forms, an online survey development company with secured data storage capabilities. Skip logic functions were implemented to reduce participant burden and survey completion time. Survey responses were anonymous.

3.2 Survey content

Using validated sources, a 75-item questionnaire was developed and reviewed by a study-panel of researchers with experiences in respiratory health, cannabis consumption and substance use behaviors. The development of the survey was guided by the LCHD framework and HBM to examine determinants that impact cannabis consumption behaviors, perception of health, pertaining to perceived severity and risk perception, and health outcomes (e.g., respiratory health) pertaining to the EA cohort. The survey was designed to be completed within 20 to 25 minutes.

Survey items were adopted from previous studies on cannabis use and respiratory health (Lee et al., 2016; Taylor et al., 2002) and from various validated sources, including the (1) *International Cannabis Policy Study (*Hammond et al., 2018); (2) the *Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU)* (Cuttler & Spradlin, 2017), and; (3) *International Study of Asthma and Allergies in Childhood (ISAAC)* questionnaire (Asher et al., 1995). One study in particular was used as a reference for questions pertaining to risk perception and the behavioral responses of the population to the COVID-19 pandemic. These questions were derived from a study survey entitled 'Risk perception and behavioral responses of the general public during the influenza A (H1N1) pandemic in Netherlands', which focused on examining perceptions and behaviors of the general public during the early phase of the Influenza A (H1N1) pandemic in the Netherlands (Bults et al., 2011).

Survey variables

1) Health Macro-contexts/Background

Genetic endowment questions included: 'What is your age?'; 'What is your sex?'; 'What is your ethnicity?'; 'What gender do you identify with?'.

Demographic questions included: What is your combined family's annual income'; 'What is your personal annual income?'; 'What is/are your main source(s) of income'; 'What is the highest degree or level of school you have completed?'; 'What is your current living situation? (I live with...)?' (Appendix B).

Social environment questions included: 'How many of your 5 closest friends use cannabis?'; 'Since the preventative measures were put in place, have you used cannabis with other people?'; 'Since the preventative measures were put in place, how easy or difficult has it been for you to get cannabis?'; 'Do you feel comfortable using cannabis in public?'.

Perceptions of cannabis use. Other explanatory variables included variables from the HBM, which addresses the individual's perceptions of the threat posed by a health problem (i.e., susceptibility and severity of cannabis related harm), and factors influencing the decision to act (perceived barriers to positive health behavior). Questions related to ***perceived susceptibility:*** "How susceptible do you think you are to serious illness related to COVID-19?" (Bults et al., 2011); "Are you aware that COVID-19 can harm the lungs", ***Perceived severity/risk:*** "How harmful do you think it is to smoke cannabis?"; "How harmful do you think it is to vape cannabis?", and ***Perceived barriers:*** "How addicted are you to cannabis?"; "Do you use cannabis for medicinal purposes?" (Hammond et al., 2018).

2) Health Micro-contexts

Behavioral pathways and systems. To examine whether participants noted a general change in cannabis consumption following legalization, EVALI and COVID-19, three questions pertaining to each event was created, followed by open-ended questions for a description of how their consumption has changed. For example, the question, "has legalization changed your cannabis use?" was determined by a dichotomous outcome. If participants chose 'yes', then they were directed to "please describe how legalization has changed your cannabis use".

Cannabis consumption measures. To address the consumption behaviors and patterns of cannabis users the following questions were included: 'How many days in your lifetime have you smoked cannabis?'; 'How many days in your lifetime have you vaped cannabis?' (Lee et al., 2016); 'What is the 'primary' method you use to vape cannabis'; 'What is the 'primary' method you use to smoke cannabis? [Please note that by 'primary', we are referring to the method that you use predominantly, or most often?]' (DFAQ-CU); 'Which of the following methods do/did you use 'regularly' when vaping cannabis? Please note that by 'regularly', we are referring to the

method(s) that you use at least 25% of the time or more'; Which of the following methods do/did you use 'regularly' when smoking cannabis?; 'When was the LAST time you vaped cannabis?'; 'When was the LAST time you smoked cannabis?';'Have you EVER mixed nicotine oil or nicotine vape juice/e-liquid products with THC or CBD oil when vaping?'; 'In the LAST 30 DAYS have you mixed nicotine oil or nicotine vape juice/e-liquid products with THC or CBD oil when vaping?'; 'On the days you smoke and/or vape cannabis, how many hours a day do you usually spend high?'.

Cannabis users were first grouped into the status of a vaper only, smoker only, or dual user based on whether they had ever vaped and/or smoked in the last 12 months. Frequent or experienced cannabis use is defined in other studies as at least 52 times or more over the previous year or 900 occasions (Hancox et al., 2015; Taylor et al., 2002) or 100 or more days of lifetime consumption (Lee et al., 2016). In this study, lifetime cannabis days of smoking and vaping were each categorized into the following binary variables: (1) occasional user (categories 1 to 2; 3 to 10; or 1 to 99) or (2) frequent user (categories 100 to 999; or more than 1000).

Frequency of smoking and vaping was assessed using two questions: 'How frequently do/did you smoke cannabis?' and 'How frequently do/did you vape cannabis?' for each of the developments: pre-legalization, post-legalization; pre-EVALI outbreak, post-EVALI outbreak; pre-COVID-19 pandemic, post-COVID-19 pandemic. Frequency was measured as a continuous outcome for each time-interval based on the following 9 categories: 0 = I did not smoke/vape, 1 = less than once a month, 2 = once a month, 3 = 2 to 3 times a month, 4 = once a week, 5 = twice a week, 6 = 3 to 4 times a week, 7 = 5 to 6 times a week, 8 = once a day, and 9 = more than once a day. These variables were derived from the DFAQ-CU, which has been deemed as a reliable

inventory for measuring frequency and quantity of cannabis forms including dried herb and concentrates (Cuttler & Spradlin, 2017).

Quantity of cannabis in relation to the specific form of cannabis was assessed for joint size and quantity, herb (grams), hash (grams), concentrates (grams), and the number of vaping cartridges used. Quantity variables were adopted from the International Cannabis Policy Study, and included reference images to help facilitate estimation of amount personally consumed (Hammond et al., 2018). These quantity measures have been helpful in enhancing reporting accuracy (Goodman et al., 2019). If participants indicated a certain form of cannabis as the primary form they use (i.e., form used predominantly or most often), they were directed to the specific form used and the quantity. For example, participants were asked: 'Do you consider dried herb as one 'primary' form of cannabis that you use?'.

Questions specific to the quantity of each form included: 'On the days you use(d) joints, what joint size is the closest to the size you personally, normally smoke(d)?'; 'On the days you use(d) joint(s), how many joints of this size do/did you personally smoke?'; 'On the days you use(d) dried herb, about how much do/did you personally use?'; 'On the days you use(d) Hash/Hashish how much did/do you personally use?'; 'On the days you use(d) concentrates about how much did/do you personally use?'; 'What size vaping cartridge do you 'primarily' use?'; 'How many vape cartridge(s) or refill(s) of this size did/do you use in a usual month?'.

Herb quantity was based on the amount measured in grams (range: 0-8 grams) or by joint size (range: 0-1.2), and the number of joints personally smoked on a typical day (range: 0-10). Hash and concentrate quantity were measured on a continuous scale in grams (range: 0-8 grams). Vaping cannabis oil/juice was determined based on the number of vape cartridges or refills used in a usual month on a continuous scale (0-8). To ensure all measures were continuous, numeric

assumptions were created for options, ‘less than the least number of grams’ indicated, and for more than the maximum number of grams. For example, for herb quantity, the option “less than 1/8 grams” used, a value of 0.0625 was inputted, for “more than ¼ ounce”, a numeric assumption of 8 was inputted. Due to a lack of data obtained for the question “what size vaping cartridge do you 'primarily' use?”, this data was excluded from analysis. For categorical response options, “I do not know” data were omitted as *missing data* for each of the variables.

Physiological Pathways and Systems. To address history of respiratory conditions and general health, the following items were extracted from the ISAAC questionnaire: ‘Have you ever had asthma’; ‘In the last 30 days, have you been sick?’; ‘Was your illness respiratory-related? (Ex: Cough, flu, cold, sore throat, runny nose)?’. In addition, respiratory symptoms related to COVID-19 were determined by asking participants: ‘Were any of your respiratory symptoms (cough, wheeze, shortness of breath, chest tightness, sore throat) related to COVID-19?’.

3) <u>Mechanisms and Regulatory Processes</u>

To address the onset of exposure in terms of cannabis smoking or vaping, the following questions were adapted from the DFAQ-CU: “How old were you when you FIRST smoked cannabis?”; “How old were you when you FIRST vaped cannabis?”.

4) <u>Respiratory Health Outcomes</u>

To examine respiratory symptoms, the following items were extracted from the ISAAC questionnaire: ‘In the last 12 months, has your chest sounded wheezy during or after exercise?’. The following questions were used because they proved sensitive to cannabis use in a previous study (Taylor et al., 2002) and also showed an impact of the vaporizer (Earleywine & Van Dam, 2010; Earleywine & Smucker Barnwell 2007):

‘Have you had wheezing or whistling in the chest in the last 12 months?’; ‘In the last 12 months, have you ever had a dry cough at night, apart from a cough associated with a cold or chest infection?’; ‘In the last 12 months, have you coughed up phlegm in the morning?’.

Pilot Testing of Survey

The survey was piloted in late April of 2020 with 11 participants between the ages of 18 to 29 representative of the study population (i.e., current cannabis users). Piloting of the survey assessed the feasibility of completing the survey and clarity of the questions. No modifications to the survey was made.

3.3 Participant recruitment

Convenience sampling was used to recruit participants from social media platforms, including Facebook and Twitter. Social media pages and accounts were created on Facebook (@OntarioTechCCPStudy) and Twitter (@OTU_CCP_Study) pertaining to the study. Advertisements containing the survey link were targeted to cannabis users by using terms and specifications suited for the age group (18 to 29 years old). Terms used to identify Facebook users’ self-reported interests included, ‘smoking’; or ‘vaping’; or ‘e-cigarettes’; or ‘cannabis’. Twitter ads and tweets involving the terms ‘cannabis’ or ‘vaping’ or ‘weed’ or ‘smoking’ were selected with corresponding hashtags, which would target individuals with interests similar to an account’s followers or likely to be interested in that type of advertisement.

Participants were also recruited from Ontario Tech University through the communication server of the institution. An email was sent to all domestic students (residing in Canada). This included both incoming spring / summer (May to August 2020) students, and the past winter (January to April 2020) cohort. The email contained details regarding the study and

procedures, as well as a link to the consent form and survey. The survey link was also advertised on the Ontario Tech News website and in a local Durham Regions News article (Follert, 2020). Recruitment and data collection occurred from May 4th, approximately 6 weeks after the declaration of the COVID-19 pandemic restrictions in Canada. Data collection continued to August 31st 2020. This study received ethics approval from the Ontario Tech University Research Ethics Board on May 4, 2020 [REB#15880].

Inclusion and Exclusion Criteria

In order to participate in this study, participants must have met the following inclusion criteria: reported smoking and/or vaping cannabis in the last 12 months, currently residing in Canada, and were 18 to 29 years old.

3.4 Data analysis

Data Cleaning

Information submitted to Google Forms was automatically converted into a Microsoft Excel Spreadsheet. This information was transferred electronically into SPSS (IBM SPSS Statistics 27 ©) for each participant. Respondent data were excluded if: there was no response to questions regarding the inclusion and exclusion criteria (n=3), age was not 18 to 29 years old (n=11), no consent was provided (n = 1), and / or smoking or vaping cannabis did not occur in the last 12 months (n=13) (e.g., only used edibles forms). In line with exploratory cross-sectional studies, I hoped to recruit a minimum sample size of n=200. The final sample consisted of 312 participants, which met the target initially established.

Objectives

i. The first objective was to examine if there was a change in inhalational routes of cannabis consumption (i.e., smoking and vaping) in relation to frequency and

quantity of various forms of cannabis for each of the time intervals: pre-legal, post-legal; pre-EVALI, post-EVALI; pre-COVID-19, post-COVID-19.

ii. The second objective was to describe sex-specific profiles of cannabis consumption (i.e. vaping and/or smoking) and exposures such as modes, form, frequency, and quantity.

iii. The third objective was to examine significant sex-specific differences in respiratory symptoms in relation to predictors of exposure profiles (e.g. mode, form, frequency, and quantity) of cannabis consumption (i.e., vaping or smoking).

Analysis

Variables were first assessed using univariate analysis, by calculating frequencies for explanatory variables in relation to all sociodemographic and participant characteristics (Appendix A). Second, bivariate analyses were conducted to determine gender-specific differences in relation to variables related to sociodemographic characteristics. Depending on the data type, chi-square (χ^2) statistics or independent *t*-test were used to compare groups. Categories with smaller n values, were combined, which increased the n value and allowed for better analysis. The variable used for the gender-specific analysis in relation to cannabis consumption were based on responses from the variable '*sex'* (male or female), since most participants identified as male or female and there was a high consistency and overlap of their responses received for gender identity.

Analysis for Objective 1

One-way repeated measures analysis of variances (ANOVAs) using Bayesian analysis were conducted to evaluate the effects of the six events over time (pre-legal, post-legal; pre-EVALI, post-EVALI; pre-COVID-19, post-COVID-19), on the dependent variables (frequency

of smoking, frequency of vaping). Bayesian models were created for each outcome measure. Analyses stratified by sex (females and males) were conducted using general linear model repeated measures ANOVA to describe differences in frequency of smoking/vaping. Post-hoc comparisons using the Bonferroni correction were conducted to determine significant between-subject differences for each time interval and outcome.

Analysis for Objective 2

To examine cannabis consumption profiles in relation to sex-specific differences, Chi-square (χ^2) and independent samples *t*-test statistics were conducted.

Analysis for Objective 3

Reporting 'yes' to at least one of four symptoms was used in analysis to examine correlates of respiratory symptoms in relation to cannabis exposure profiles stratified by sex. Three sets of analyses were performed. First, bi-variate analyses were conducted to describe the frequency of respiratory symptoms reported by participants. Specifically, Chi-square (χ^2) statistics was used to compare participants who did and did not report respiratory health outcomes, in relation to sex (female vs. male). Second, χ^2 test (categorical variables) and independent *t*-tests (continuous variables), were used to compare participants who did and did not report respiratory health outcomes, in relation to cannabis exposure profiles (method, mode, form, frequency and quantity). Third, all explanatory variables that were significant in the bi-variate analyses ($p < 0.20$) in relation to sex-specific differences and exposure profiles of cannabis consumption, were entered into a binary logistic regression model to identify significant predictors of reporting at least one respiratory symptom. These analyses were examined for the overall sample and stratified by sex to evaluate effects in males and females separately. For each model, entry of independent variables was conducted using the enter method

and using a significance level of $p < 0.05$. The Hosmer-Lemeshow test was used as a goodness-of-fit-measure.

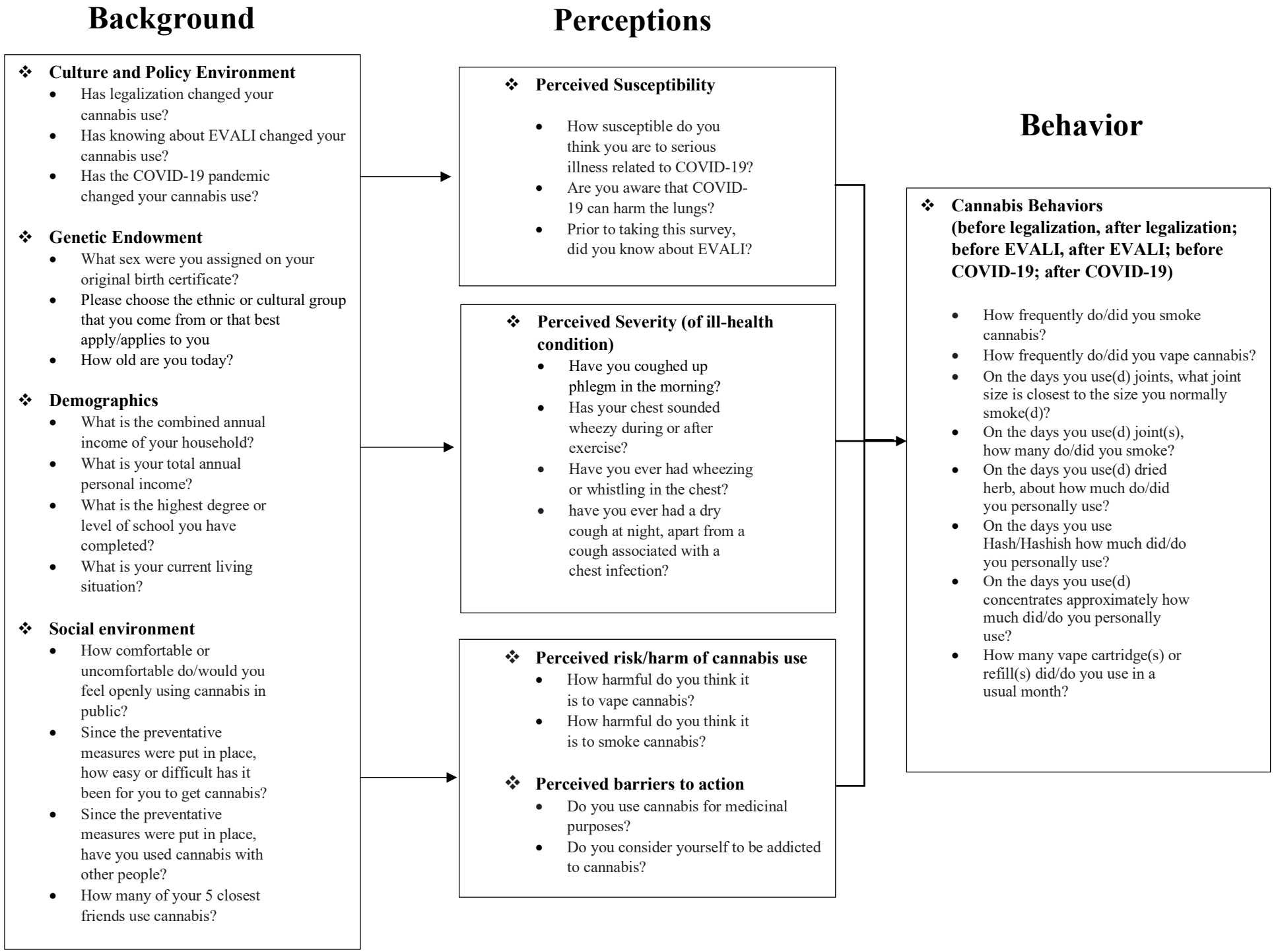


Figure 3.1. Schematic diagram of the adopted components of the Health Belief Model in relation to cannabis consumption (Rosenstock, 1994).

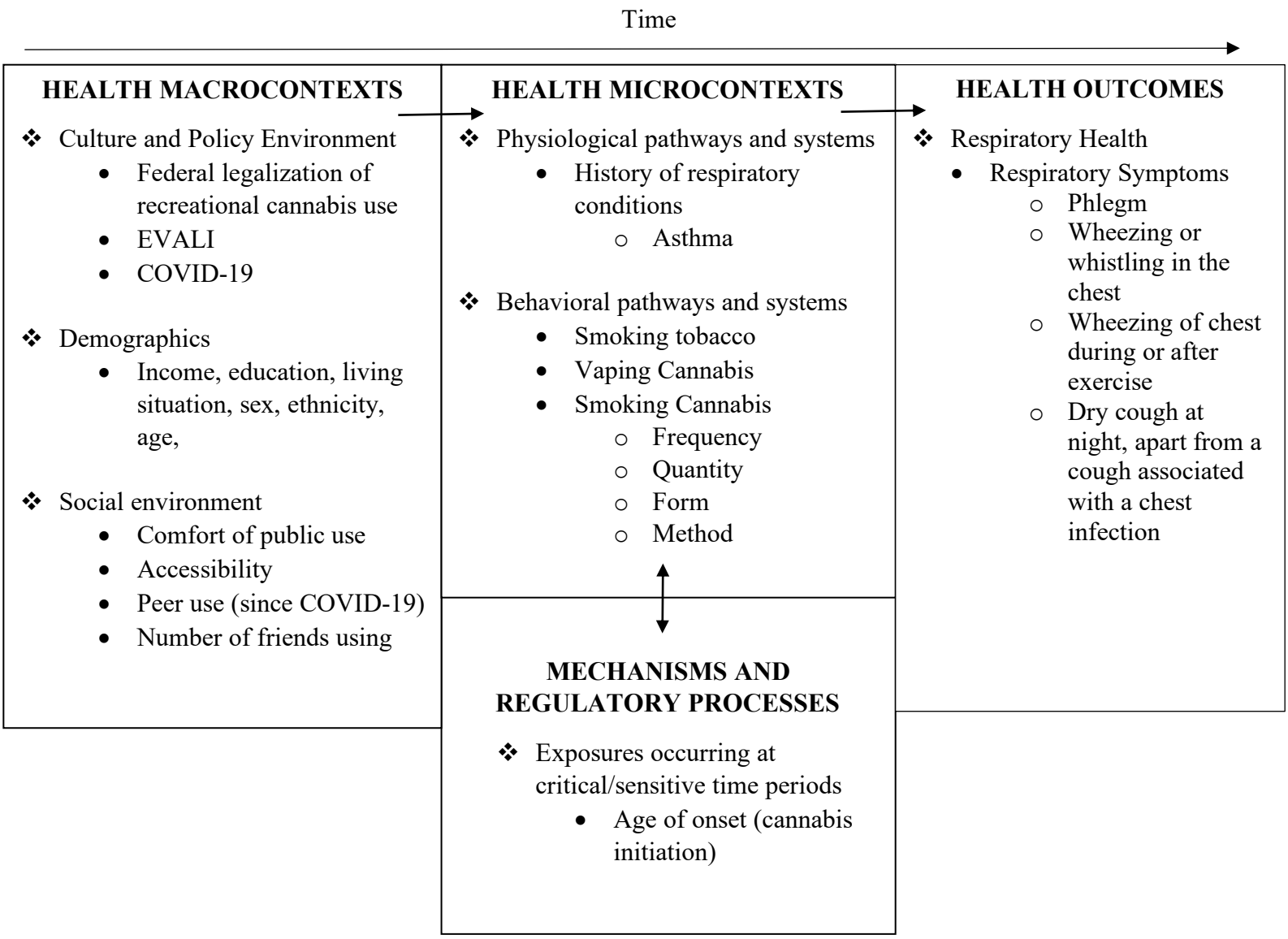


Figure 3.2. Application of the Life Course Health Development Framework to examine variables of Respiratory Health in relation to cannabis exposure profiles of EA in Canada (Halfon & Hochstein, 2002).

References for Chapter 3

Asher, A., Keil, U., Anderson, H., Beasley, R., Crane, J., Martinez, F., … Stewart, A. (1995). International Study of Asthma and Allergies in Childhood (ISAAC). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/7789502

Bults, M., Beaujean, D. J., de Zwart, O., Kok, G., van Empelen, P., van Steenbergen, J. E., ... & Voeten, H. A. (2011). Perceived risk, anxiety, and behavioural responses of the general public during the early phase of the Influenza A (H1N1) pandemic in the Netherlands: results of three consecutive online surveys. *BMC public health*, *11*(1), 1-13.

Cuttler, C., & Spradlin, A. (2017). Measuring cannabis consumption: psychometric properties of the daily sessions, frequency, age of onset, and quantity of cannabis use inventory (DFAQ-CU). PloS one, 12(5). https://doi.org/10.1371/journal.pone.0178194

Edgar, T. W., Manz, D. O., & Manz, D. O. (2017). Exploratory study. *Research methods for cyber security*, *29*, 95-130.

Goodman, S., Leos-Toro, C., & Hammond, D. (2019). Methods to Assess Cannabis Consumption in Population Surveys: Results of Cognitive Interviewing. Qualitative Health Research, 29(10), 1474-1482. doi:10.1177/1049732318820523

Greaves, L., & Hemsing, N. (2020). Sex and gender interactions on the use and impact of recreational cannabis. *International journal of environmental research and public health*, *17*(2), 509. doi:10.3390/ijerph17020509

Halfon, N., & Hochstein, M. (2002). Life Course Health Development: An Integrated Framework for Developing Health, Policy, and Research. The Milbank Quarterly, 80(3), 433–479. http://doi.org/10.1111/1468-0009.00019

Harris-Lane, L., Winters, E., & Harris, N. (2020). Emerging Adult Perceptions of Cannabis Use Based on Age and Sex of User. Emerging Adulthood, 2167696820930862. https://doi-org.uproxy.library.dc-uoit.ca/10.1177/2167696820930862

Hammond D., Goodman S., Leos-Toro C., Wadsworth E., Reid JL., Hall W., Pacul R., Driezen P., George T., Rehm J., Werb D., Boudreau C., Porath A., Abramovic H., Elliot R. International Cannabis Policy Survey. August 2018

Rodriguez-Besteiro, S., Tornero-Aguilera, J. F., Fernández-Lucas, J., & Clemente-Suárez, V. J. (2021). Gender differences in the covid-19 pandemic risk perception, psychology and behaviors of spanish university students. *International Journal of Environmental Research and Public Health*, *18*(8), 3908

Rosenstock, I. M., Strecher, V. J., & Becker, M. H. (1994). The health belief model and HIV risk behavior change. In *Preventing AIDS* (pp. 5-24). Springer, Boston, MA

Stebbins, R. A. (2001). What is exploration. *Exploratory research in the social sciences*, 2-17.

Overview of Chapter Formats

The following three chapters are divided into three stand-alone manuscripts. Chapter 4 of this thesis represents the first manuscript, which has been formatted according to submission guidelines, and contains full details and sections necessary intended for submission to the *Journal of Substance Use & Misuse*. For that purpose, and in the interest of reducing redundancy, the methodology sections for manuscripts on chapters 5 and 6 have been modified to include less information.

Chapter 4. Manuscript 1

Increases in cannabis frequency among emerging adults in relation to policy and public health developments: A cross-sectional exploratory study

Susan Yousufzai [a]*, Adam Cole[a], Mika Nonoyama[a], and Caroline Barakat[a]

[a]*Faculty of Health Sciences, Ontario Tech University, Oshawa, Canada*

Submitted to: *Substance Use and Misuse*

4.1 Abstract

Background: Rates of cannabis use appear to be highest among emerging adults (EA). Evidence suggests that alternate inhalational methods of cannabis consumption (e.g., vaping) in addition to smoking (i.e., dual use) have become a prevalent mode of consumption among this population. Substance use/misuse, in particular, is a problem that peaks during emerging adulthood and may be influenced by extreme economic, social and community deviations, such as altering legislative policy changes, public health concerns, and pandemics. Specifically, cannabis consumption trends may change among at-risk populations due to the legalization of recreational cannabis in Canada, the declaration of the "e-cigarette or vaping product use associated lung injury" or 'EVALI' outbreak, and the 'COVID-19' pandemic. ***Objectives:*** We aimed to examine self-reported changes in frequency of cannabis use among EA in Canada (N=312): pre-legalization, post-legalization; pre-EVALI, post-EVALI; pre-COVID-19, post-COVID-19, by sex. ***Results****:* There was a gradual increase in average frequency of smoking and vaping over time from the pre-legalization period (2018) to the COVID-19 pandemic period (2020). Males reported higher frequencies of cannabis smoking and vaping compared to females. ***Conclusions:*** Cannabis patterns may increase among vulnerable populations over time, and may be further compounded by changes in social and environmental conditions. There are important sex differences in behavioral factors of cannabis use in EA. These findings may facilitate the development of sex-informed prevention and intervention programs for policy measures to address cannabis-attributable outcomes in the face of contextual factors that promote use, such as public emergencies or changes in policy landscapes.

Keywords: COVID-19; cannabis; Canada; emerging adults; frequency

4.2 Introduction

Rates of cannabis use appear to be higher among EA than other age groups (Halladay et a., 2018; Stone et al., 2012). In fact, following the legalization of recreational cannabis consumption in Canada, estimates of prevalence in 2019 were highest among 18 to 24 years old individuals at 33.3%, compared to 5.9% to 24.4% among the 15-17, 25-44, 45-64 and 65+ age groups (Rotermann, 2020). Emerging adulthood is recognized as a biologically and socially constructed sensitive period of development that occurs between the ages of 18 to 29 years (Arnett et al., 2014). Critical physiological and behavioral changes that characterize this period, such as brain development, and habit formation, make EA particularly vulnerable to substance experimentation and related health outcomes (Ames et al., 2020; Halladay et al., 2018). Specifically, experimentation with cannabis, onset of patterned use, and establishment of chronic problematic consumption are more pronounced during this age period (Leos-Toro et al., 2019; Stone et al., 2012).

Cannabis consumption may be reinforced by ease of accessibility due to legal recreational use in Canada, coinciding with the transition into emerging adulthood (i.e., 18 or 19 years in Canada) (Parnes et al., 2018). This may influence sex-specific differences in consumption trends of young consumers. Cannabis use is more prevalent among males than females (Greaves & Hemsing, 2020), which may reflect traditional gender-norms, greater sensitivity to cannabis effects (Cooper & Craft, 2018), and perceptions of greater harm among females than males (Harris-Lane et al., 2020). However, it is unclear how the political amendment may affect smoking and vaping consumption trends in relation to sex among EA and what implications various methods and forms of cannabis consumption may present in the long-term.

Recently alternate inhalational methods of cannabis consumption (e.g., vaping) in addition to smoking (i.e., dual use) have become prevalent among EA (Cassidy et al., 2018; Jones et al., 2016). This influx has led to increased popularity of using processed cannabis vaping liquids and oils composed of chemical agents such as flavoring substances (e.g., terpenes), thinning agents (i.e., propylene) and vitamin E acetate, which have been linked to the "silent" epidemic of 'e-cigarette, or vaping, product use–associated lung injury' (EVALI) (Aberegg et al., 2020).

Evidence suggests that the safety narrative around e-cigarette use is changing and influencing cessation intentions (Kreslake et al., 2021; Patel et al., 2020); however, it is unknown whether such public health outbreaks (i.e., EVALI) effectively encourage refraining from cannabis vaping and if frequency trends have changed among EA. Given the respiratory health risks of severe acute respiratory syndrome (SARS-CoV-2) (Sohrabi et al., 2020), it follows that smoking and vaping were considered health-risk behaviors to refrain from during the COVID-19 pandemic to reduce susceptibility to infection and magnification of adverse clinical prognosis (Borgohni et al., 2020; Dubey et al., 2020).

For EA in particular, lack of perceived susceptibility to severe illness associated with COVID-19 (Yang et al., 2020), high cannabis consumption rates, and vulnerability to substance use as a coping mechanism during the pandemic, may lead to increased consumption (Germani et al., 2020; Hyman and Sinha, 2009; Lee et al., 2007). Moreover, at the individual-level these social and environmental changes may represent a risk-factor for behaviors that did not exist prior to the pandemic, and may predict a higher probability of infection in cannabis users that smoke or vape (Gaiha et al., 2020; Ornell et al., 2020). Thus, it is critical to consider the impact

of social and environmental changes (such as the COVID-19 pandemic) on conventional and social EA users, which may influence patterns of consumption.

There is limited evidence of cannabis consumption during prior respiratory-associated disease outbreaks. For example, research regarding substance use patterns during the 2008 SARS public health crisis have focused on alcohol and tobacco (Esterwood & Saeed, 2020), which have shown sustained increase in substance use (Wu et al., 2008). However, the shift in policy landscape and the risk of EVALI are novel factors to navigate during the current SARS-2 outbreak. Emerging evidence points to increases in frequency of cannabis days (Dumas et al., 2020), and joints smoked (Van Laar et al., 2020) following the declaration of the COVID-19 pandemic. In addition, higher odds of increased cannabis use have been associated with Canadians 18-29 years old (Imtiaz et al., 2020).

Accordingly, it is important to examine the compounded risks of COVID-19 on cannabis consumption behaviors at a time where liberated cannabis laws and susceptibility to respiratory infections from diverse methods are simultaneously increasing health risks and influencing cultural substance norms. This exploratory cross-sectional study aimed to examine if there was a change in self-reported frequency of inhaled routes of cannabis consumption (i.e., smoking and vaping) following the legalization of recreational cannabis use in Canada, the EVALI epidemic, and COVID-19 pandemic, among male and female EA in Canada. We hypothesized that most EA would increase their frequency after legalization, but decrease frequency after the declaration of EVALI and the COVID-19 pandemic. In addition, females and males would increase their frequency post legalization, whereas, a higher proportion of females than males would decrease their frequency of consumption (vaping/smoking) following the declaration of EVALI and COVID-19.

4.3 Materials and Methods

Participant recruitment

In order to participate in this study, participants must have met the following inclusion criteria: reported smoking and/or vaping cannabis in the last 12 months, currently lived in Canada, and were 18 to 29 years old. The survey was restricted to the English language, and consent was required to participate. Respondents that met the inclusion criteria and consented were then directed to the survey questions, which was designed to take 20 to 25 minutes to complete. No compensation was provided. All self-identifying information was removed and saved separately from the dataset, ensuring anonymity of participants.

Convenience sampling was used to recruit participants ages 18 to 29 from social media platforms. Social media pages and accounts were created on Facebook (@OntarioTechCCPStudy) and Twitter (@OTU_CCP_Study) pertaining to the study. Advertisements were created on each social media platform, and targeted to cannabis users by using terms and specifications suited for the age group (18 to 29 years old) and specifying country of residence (i.e., Canada), through proprietary marketing algorithms. Terms used to identify Facebook users' self-reported interests included, 'smoking'; 'vaping'; 'e-cigarettes'; 'cannabis'. Twitter ads and tweets involving the terms 'cannabis'; 'vaping'; 'weed'; 'smoking' was selected with corresponding hashtags, which targeted individuals with similar interests.

Participants were also recruited from Ontario Tech University through the communication server of the institution. An email was sent to all domestic students (residing in Canada). This included both incoming spring/summer (May to August 2020) students, and the past winter (January to April 2020) cohort. The survey link was also advertised on the Ontario Tech News website and in a local Durham Regions News article (Follert, 2020). The email and

advertisements contained details regarding the study and procedures, as well as a link to the consent form and survey hosted on Google Forms.

Recruitment and data collection occurred from May 4, 2020, approximately 6 weeks after the declaration of the COVID-19 pandemic restrictions in Canada. Data collection continued to August 31, 2020. This study received ethics approval from the Ontario Tech University Research Ethics Board on May 4, 2020 [REB#15880].

Survey items

The survey was developed considering previous studies on cannabis consumption (Lee et al., 2016; Hancox et al., 2015; Taylor et al., 2000) and using various validated sources, including the *International Cannabis Policy Study* (Hammond et al., 2018), the *Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU* (Cuttler & Spradlin, 2017), and the *International Study of Asthma and Allergies in Childhood (ISAAC)* questionnaire (Asher et al., 1995). A 75-item survey was developed and reviewed by a study-panel of researchers with experiences in respiratory health, cannabis consumption and substance use behaviors. The survey was piloted in late April 2020 with 11 participants between the ages of 18 to 29 who were current cannabis users. Piloting of the survey assessed the feasibility of completing the survey and clarity of the questions. No significant modifications to the survey were made.

From Ontario Tech University 109 individuals participated in the survey. From social media platforms 234 individuals participated in the survey. From both platforms, results of 343 individuals were reviewed, of which 312 were eligible. Respondents were excluded if they: accessed the survey but did not answer any questions regarding the inclusion and exclusion criteria (n=3), were not 18-29 years old (n=11), did not smoke or vape cannabis in the last 12 months (n=13) (e.g., only used edibles forms), or did not consent (n = 3).

Measures

Explanatory variables

In relation to assessing changes in patterns of consumption due to the events, a question first asked participants if they knew of EVALI prior to taking the survey. It was assumed that due to the relatively low cases of EVALI in Canada (Government of Canada, 2020), it was important to determine whether users were aware of this outbreak before asking participants if their cannabis consumption had changed as a result of EVALI. Participants were asked, "Prior to taking this survey did you know about EVALI?". In addition, participants awareness of harm of COVID-19 risks was assessed; "Are you aware that COVID-19 can harm the lungs?", with response options of 'yes' and 'no'. To assess if their frequency had changes, three questions pertaining to each event (legalization, EVALI, and COVID-19) was created, asking participants if the event had changed their consumption. Participants were quired: "Has legalization changed your cannabis use?"; "Has knowing about EVALI changed your cannabis use?"; "Has the COVID-19 pandemic changed your cannabis use?". All responses were dichotomized ("yes" or "no").

Cannabis consumption measures. Participants were asked two questions regarding their smoking or vaping consumption method in the last 12 months: "In the LAST 12 months did you ever smoke cannabis?"; "In the LAST 12 months did you ever vape cannabis?". These respondents were then defined as a vaper only, smoker only, or dual user if they had only vaped, only smoked, or reported both methods within the last 12 months, respectively. Participants that reported smoking and/ or vaping, were then directed to report frequency measures for each method over the time periods corresponding to the three events.

Frequency measures. Two questions measured frequency patterns of smoking and / or vaping cannabis on a usual day before and after the occurrence of all three events. Participants were asked: "How frequently did you smoke cannabis: before Legalization (approximately October, 2018); after Legalization; before EVALI (approximately November, 2019); after EVALI; before imposed COVID-19 preventative measures (approximately March, 2020); after imposed COVID-19 preventative measures?". Response options included, I did not smoke, less than once a month (e.g., 2-6 times/year), once a month, 2-3 times a month, once a week, twice a week, 3-4 times a week, 5-6 times a week, once a day, and more than once a day (Cuttler & Spradlin, 2017). The same categorization frequencies were used to measure vaping.

Changes or persistence in frequency of cannabis consumption between two consecutive events (i.e., pre-legalization, post-legalization; pre-EVALI epidemic, post-EVALI epidemic; pre-COVID-19 pandemic, post-COVID-19 pandemic) were used to classify an increase, decrease or no change in consumption. If a participant indicated changing from a lower to a higher category of smoking or vaping frequency (e.g., going from less than once month to once a month) it was classified as an 'increase'; if they indicated decreasing from one frequency category to another (e.g., going from once a day to 5-6 times a week) it was classified as a 'decrease'; and 'no change' was determined if the frequency was the same between two consecutive events. If users indicated 'I do not know' for either before or after an event for frequency it was regarding as missing data. Missing data were limited. For all smoking and vaping frequency variables, missing data ranged from 0.3% to 6.1%.

Demographics. Participants reported on demographic data (sex, ethnicity, income, education, living situation). Household annual income was grouped into three categories ('less than $50,000', 'between $50,000 but less than $100, 000', 'greater or equal to $100,000'), and

personal income was grouped into 'less than $20,000' or 'greater than $20,000' to create larger *n* values for each income level. The responses "I do not know" and "prefer not to say" were treated as missing data. For personal income 7.7% were missing, and 1.3% for living situation. For household income 9.9% chose not to answer.

4.4 Data analysis

Data were analyzed using SPSS v 27 (IBM SPSS Statistics 27 ©). Descriptive statistics were used to examine proportions of frequency of smoking and vaping categories reported, frequencies across demographic variables and participant characteristics. Chi-squared (χ^2) and t-tests were used for bivariate comparison of categorical and continuous variables for sex differences in demographic characteristics (age, ethnicity, education level, income, living situation), cannabis consumption methods (smoking/vaping), and awareness of EVALI and respiratory health risks related to COVID-19.

One-way repeated measures analysis of variances (ANOVAs) using Bayesian analysis were conducted to evaluate the effects of the six events over time (pre-legal, post-legal; pre-EVALI, post-EVALI; pre-COVID-19, post-COVID-19), on the dependent variables (frequency of smoking, frequency of vaping). Bayesian models were created for each outcome measure. The Bayes factor was determined to indicate statistical significance ($p < 0.05$) using the estimation method for Rouder's mixed design. Bayes factor test yields a *BF* quantifying how well the alternative hypothesis (H_1) predicts the empirical data relative to the null hypothesis (H_0) (Jeffreys, 1961; Lee & Wagenmakers, 2014). The strength of the evidence relies on BFs above 3 for the alternative hypothesis and below 0.33 for the null hypothesis, while values between approximately ⅓ and 3 indicate that the data are insensitive (Beard et al., 2016).

Analyses stratified by sex (females and males) were conducted using general linear model repeated measures ANOVA to describe differences in frequency of smoking/vaping. Post-hoc comparisons using the Bonferroni correction were conducted to determine significant between-subject differences for each time interval and outcome.

4.5 Results

Demographic and cannabis consumption characteristics

Table 4.1 summarizes the distribution of sociodemographic characteristics and cannabis consumption profiles for the study sample. Overall, 61% were female, with a mean age of 23 years. The majority of participants were of Caucasian/White descent (males: 50%, females: 62%). There was a significant difference in education level and household income among males and females, in which female participants had a higher level of education compared with male participants, while male participants reported a higher household income compared with female participants ($p = .001$). Overall, 98% of participants had ever smoked cannabis, 55% had ever vaped cannabis, and 53% had smoked and vaped cannabis in the last 12 months. Male cannabis users were more likely to have ever vaped cannabis than females in the last 12 months (63% vs. 49%, $\chi^2 (1) = 5.39$, $p < 0.05$), but the prevalence rate of smoking was equal (98%). Similarly, males had a higher prevalence of dual use (smoking and vaping cannabis) than females (61% and 48%, respectively). Only five participants reported ever vaping cannabis in the last 12 months with no cannabis smoking.

Table 4.1. Sociodemographic characteristics and cannabis consumption profiles of study population in relation to sex-specific differences (n=312).

Variable	Classification	Mean (SD)/n (%)		*p*-value[a]
		Male	**Female**	
		123 (39.4)	189 (60.6)	
Age				.134
		23.15 (3.5)	22.56 (3.3)	
Ethnicity				**.046**
	Non-white/mixed	61 (49.6)	71 (37.6)	
	White	62 (50.4)	118 (62.4)	
Education				**.001**
	High school or less	40 (32.5)	36 (19.0)	
	College	30 (24.4)	32 (16.9)	
	University or higher	53 (43.1)	121 (64.0)	
Household Income				**.001**
	<$50,000	15 (19.0)	59 (43.7)	
	$50,000 - < $100, 000	27 (34.2)	37 (27.4)	
	≥$100,000	37 (46.8)	39 (28.9)	
	Prefer not to say *(missing)*	9 (7.3)	5 (2.6)	
	I do not know *(missing)*	23 (18.7)	33 (17.5)	
Personal income				.774
	Less than $20,000	63 (57.3)	105 (59.0)	
	More than $20,000	47 (42.7)	73 (41.0)	
Current living situation				.067
	Parent(s)/Guardian(s)	71 (59.2)	83 (44.1)	
	Partner/Spouse	13 (10.8)	36 (19.1)	
	Roommates(s)	20 (16.7)	42 (22.3)	
	Family/Children	4 (3.3)	11 (5.9)	
	I live alone	12 (10.0)	16 (8.5)	
Ever smoked in the last 12 months				.979
	Yes	121 (98.4)	186 (98.4)	
	No	2 (1.6)	3 (1.6)	
Ever vaped in the last 12 months				**.020**
	Yes	77 (62.6)	93 (49.2)	
	No	46 (37.4)	96 (50.8)	
Cannabis user status				.065
	Vaper only	2 (1.6)	3 (1.6)	
	Smoker only	46 (37.4)	96 (67.6)	
	Dual user	75 (61.0)	90 (47.6)	
Awareness of EVALI				.795
	Yes	29 (23.6)	47 (24.9)	
	No	94 (76.4)	142 (75.1)	
Awareness of COVID-19 associated respiratory risks				.168
	Yes	119 (96.7)	187 (98.9)	
	No	4 (3.3)	2 (1.1)	
Changes in use due to legalization				.936
	Yes	54 (45.8)	80 (46.2)	
	No	64 (54.2)	93 (53.8)	

Changes in use due to EVALI				.558
	Yes	4 (16.0)	5 (11.1)	
	No	21 (84.0)	40 (88.9)	
Changes in use since pandemic				.852
	Yes	66 (55.9)	102 (54.8)	
	No	52 (44.1)	84 (45.2)	

Note: Categorical data are presented as frequency (percentage). Continuous data are presented as mean SD. [a]*p*-values were calculated with chi-square (categorical data) and unpaired t-tests (continuous data).

Changes in frequency patterns over time

Figures 4.1 and 4.2 show changes in the proportion for frequency of smoking and vaping respectively, before legalization to after the declaration of the COVID-pandemic. Before legalization, 15.4% (47/306) of users reported not smoking. More than half of these individuals (51.1%) reported smoking less than once a month (23/45) after legalization. A smaller proportion (6.7%) increased their frequency drastically to smoking more than once a day. A third of users (33.3%) smoking once a day before legalization, increased their frequency to more than once a day after legalization (6/18). After EVALI, 11.1% of those that reported smoking less than once a month before EVALI (n=54) transitioned to not smoking. In contrast, 17.4% of users that reported smoking once a day increased their frequency to more than once a day (4/23). After COVID-19, 14.4% (45/306) reported not smoking. A high proportion of users (45.9%) that were smoking less than monthly before COVID-19 reported not smoking since COVID-19 (17/37). Users that increased their frequency were mostly those that reported smoking weekly or daily. 18.5% of users smoking 3-4 times a week increased their frequency to once a day (5/27). In addition, 38.5% of users that smoked once a day before the pandemic, increased their frequency to more than once a day (10/26) following the declaration of the pandemic.

Almost half of users (48.5%) that reported vaping (n=170), did not vape before legalization. Of individuals that did not vape before legalization (n=82), 42.7% reported vaping

less than once a month after legalization, 15.9% increased to weekly vaping, while 3.7% increased to daily use. During the time period before and after EVALI, 36.6% of individuals that did not vape, increased their frequency to less than once a month (15/41), while 7.3% increased to weekly use. Majority of users (91.7%) vaping more than once a day sustained this frequency after the EVALI outbreak (11/12). The proportion of users vaping more than once a day increased from 5.3% to 8.5% from before to after COVID-19. Of users that were vaping 3-4 times a week prior to COVID-19 (n=6), 33.3% increased to vaping more than once a day. Of those that were vaping twice a week (n=9), 55.6% increased their frequency to 3-4 times a week. A smaller proportion that did not vape prior to COVID-19 (n=37), increased their frequency to less than once a month (8.1%). Of users that reported vaping less than once a month (n=58) before COVID-19, 24.1% decreased their frequency (did not vape) after the COVID-19 pandemic.

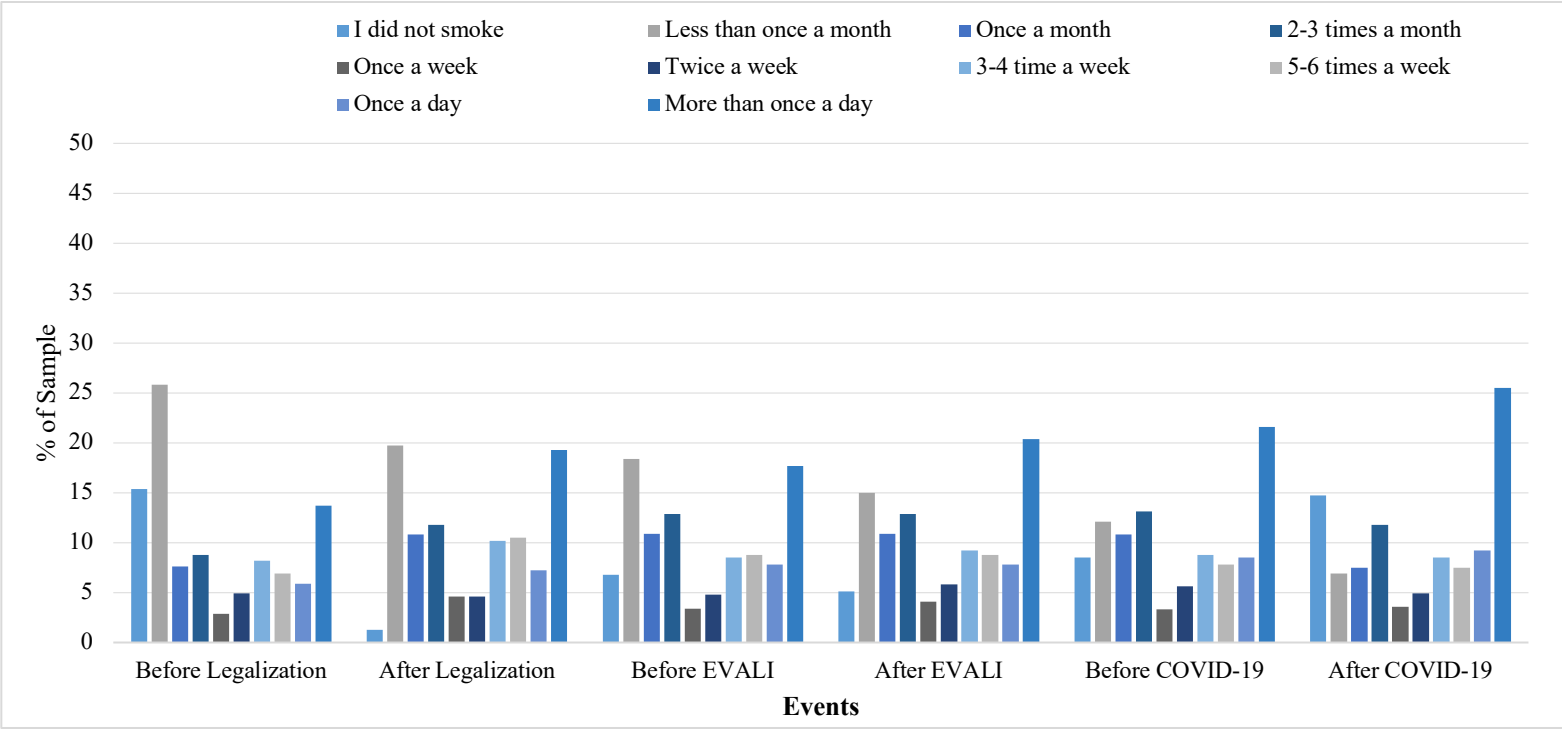


Figure 4.1. Frequency of smoking cannabis before and after each event: Legalization, EVALI, and COVID-19 (n=306).

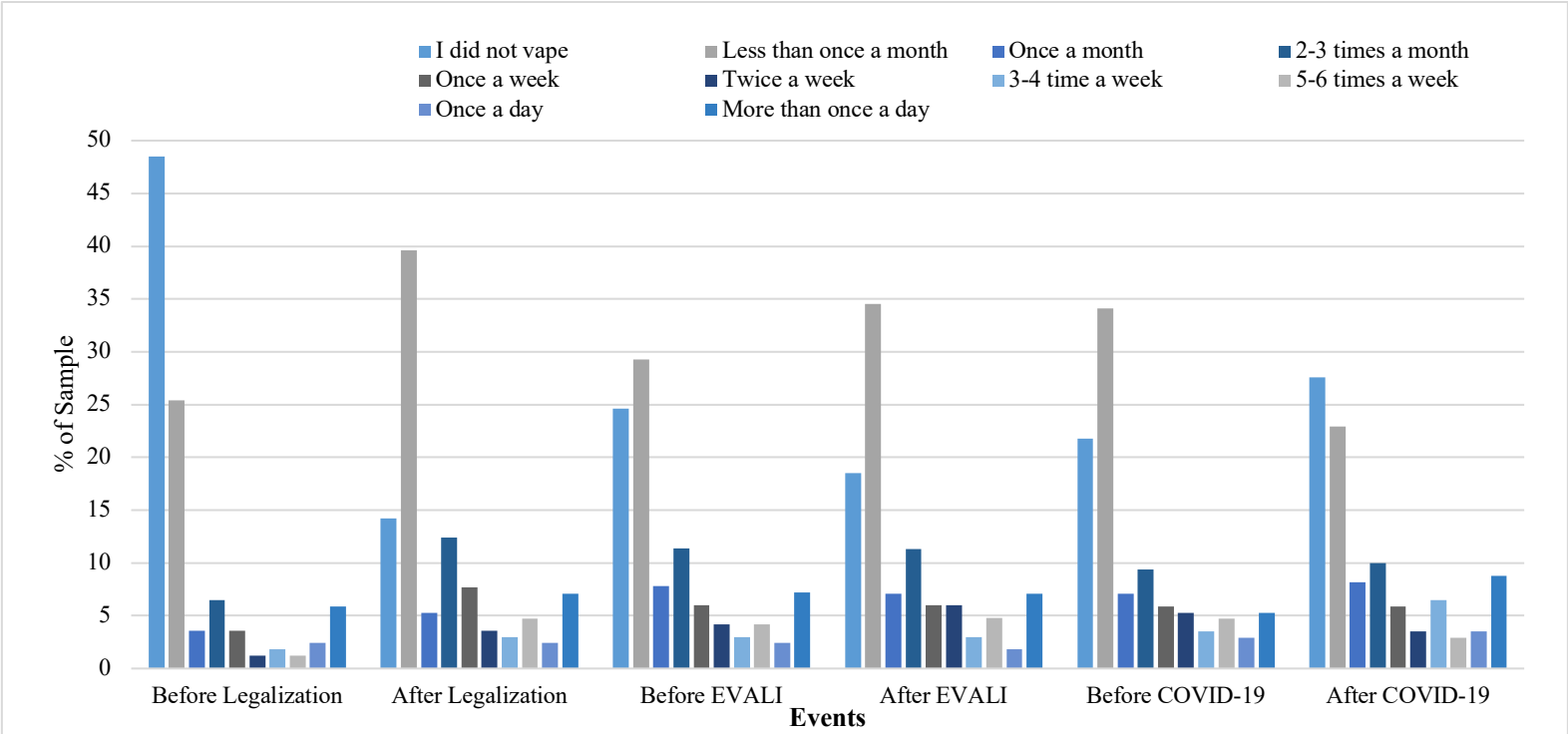


Figure 4.2. Frequency of vaping cannabis before and after each event: Legalization, EVALI, and COVID-19 (n=170).

Sex-specific changes

Cannabis consumption frequency in relation to events

Almost half of male and female participants reported changing their cannabis consumption as a result of legalization (46%). Of cannabis users that reported knowing about EVALI (n=76), very few reported changing their cannabis use in response to EVALI (3%). Although more males (16%) than females (11%) reported a change in relation to EVALI. In addition, more than half of males (56%) and females (55%) reported changing their consumption after the declaration of the COVID-19 pandemic (Table 4.1). Figures 4.3 (a-b) and 4.4 (a-b) and Table 4.2 show specific changes for males and females in relation to frequency of smoking and vaping, respectively for each event. There were no significant differences between the proportion of males and females that reported increasing, decreasing, or not changing their frequency of smoking and vaping in relation to each event period [Figures 4.3 (a-b) and 4.4 (a-b)].

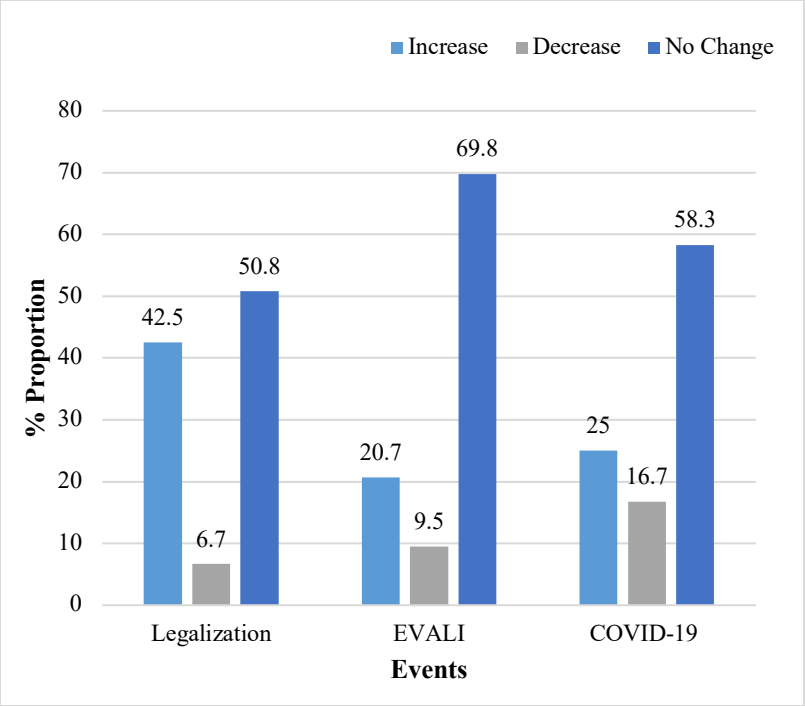


Figure 4.3a. Proportion of male cannabis smokers (n = 120) who report increasing, decreasing, or maintaining their cannabis smoking frequency as a result of three public health events: Legalization, declaration of EVALI, and the implementation of the COVID-19 pandemic.

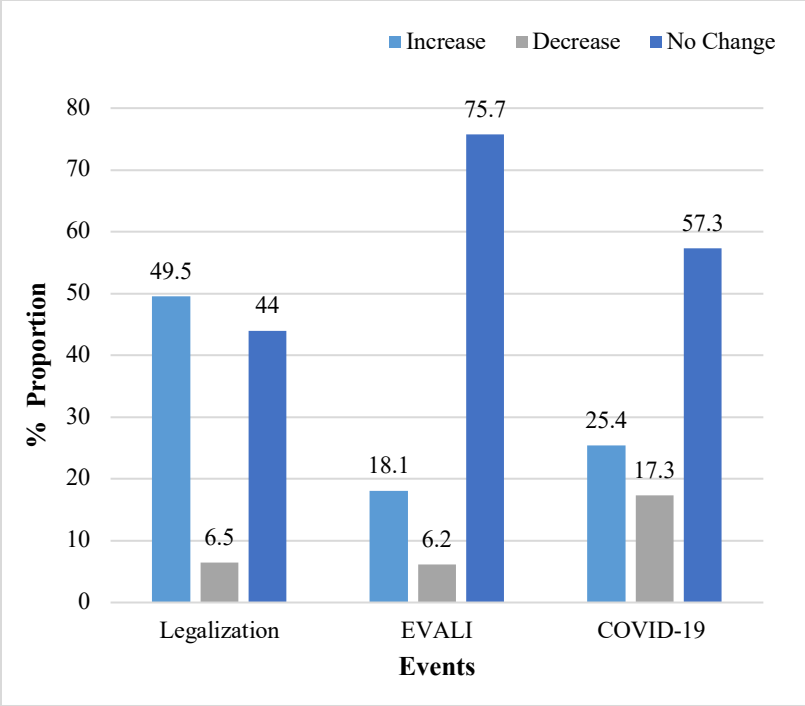


Figure 4.3b. Proportion of female cannabis smokers (n = 185) who report increasing, decreasing, or maintaining their cannabis smoking frequency as a result of three public health events: Legalization, declaration of EVALI, and the implementation of the COVID-19 pandemic.

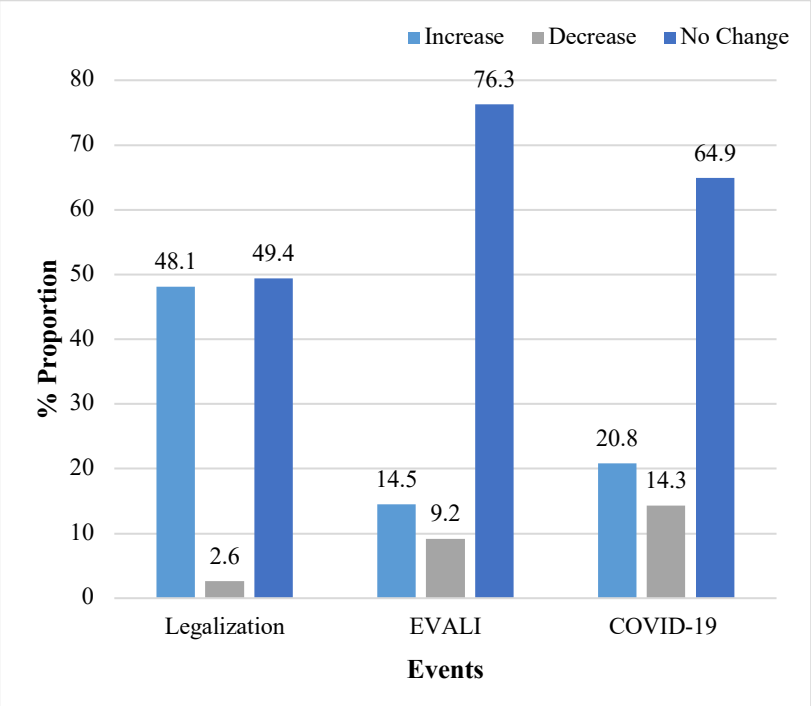


Figure 4.4a. Proportion of male cannabis vapers (n = 77) who report increasing, decreasing, or maintaining their cannabis vaping frequency before and after: Legalization, declaration of EVALI, and the implementation of the COVID-19 pandemic.

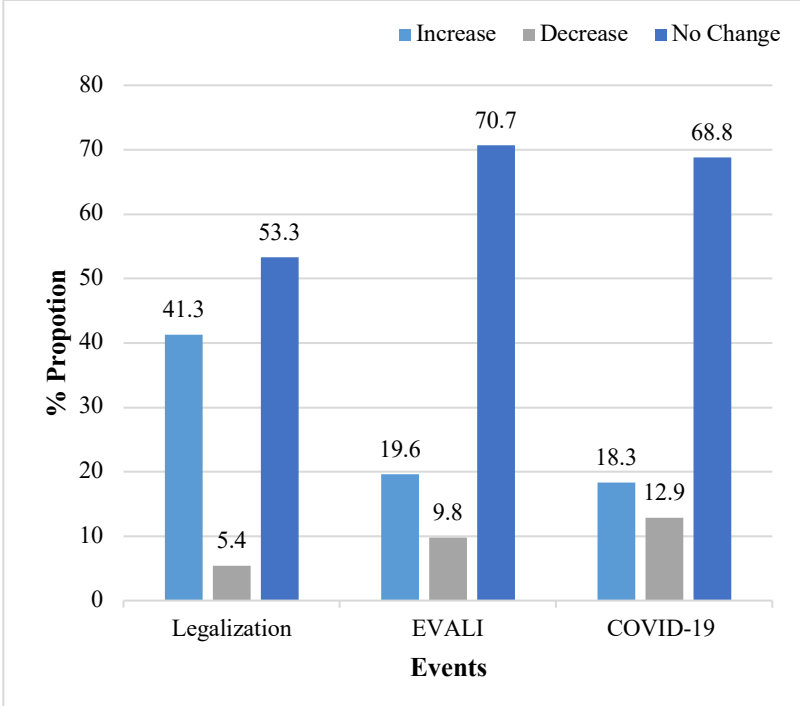


Figure 4.4b. Proportion of female cannabis vapers (n=93) who report increasing, decreasing, or maintaining their cannabis vaping frequency before and after: Legalization, declaration of EVALI, and the implementation of the COVID-19 pandemic.

Changes in average frequency of smoking and vaping

The occurrence of events elicited statistically significant changes in smoking frequency (*Bf* (14) = 2.004E+29), showing strong evidence for an effect on smoking frequency over time (*Bf* >3). Analyses separated by sex show statistical significance for changes in smoking frequency of smoking for males (F (2.46, 277.561) = 8.480), p <0.001) and females (F (2.92, 513.225) = 27.968, p <0.001). Although there was an increase in smoking frequency at each event, post-hoc analyses for both sexes revealed only a significant increase before and after legalization (p<0.001) (Table 4.2).

There was a statistically significant change in vaping frequency over time, showing strong evidence for H_1 over H_0 (*Bf* >3) (*Bf* (14) = 5321169352). This difference was significant for females (F (3.15, 283.798) = 6.168, p =.002) and males (F (3.30, 244.120) = 8.458, p <0.001), showing an increase before and after each event, and an overall increase from before legalization to after COVID-19. For before and after legalization, a post-hoc Bonferroni test revealed a significant increase for males and females in vaping frequency (p <0.001) (Table 2).

Overall, average changes over time in frequency trends for both smoking and vaping show that the average frequency of use is lower at the start of each new event (before) relative to the end of the previous one, with the lowest average frequency indicated before legalization.

Table 4.2. Changes in the overall average frequency of cannabis smoking and vaping for the total sample population (n=312) and males and females, before and after 3 public health events: Legalization of recreational cannabis in Canada, EVALI epidemic, and COVID-19.

	Min-Max	Legalization		EVALI		COVID-19		*p*-value
		Before M (SD)	After M (SD)	Before M (SD)	After M (SD)	Before M (SD)	After M (SD)	
Smoking								
Total n = 291	0-9	3.72 (3.25)	4.81 (3.06)	4.53 (3.14)	4.81 (3.10)	4.84 (3.21)	4.99 (3.38)	<0.001‡
Males n = 114	0-9	4.60 (3.35) [a]	5.61 (2.94) [a]	5.25 (3.11)	5.50 (2.97)	5.42 (3.09)	5.47 (3.37)	<0.001†
Females n = 177	0-9	3.15 (3.06) [a]	4.30 (3.04) [a]	4.06 (3.07)	4.37 (3.11)	4.46 (3.24)	4.68 (3.43)	<0.001†
Vaping								
Total n = 166	0-9	1.66 (2.61)	2.69 (2.69)	2.53 (2.76)	2.68 (2.73)	2.52 (2.68)	2.75 (2.95)	<0.001‡
Males n=75	0-9	2.03 (2.96) [a]	3.31 (2.95) [a]	3.11 (3.03)	3.21 (3.02)	3.04 (3.0)	3.23 (3.19)	<0.001†
Females n=91	0-9	1.35 (2.26) [a]	2.19 (2.36) [a]	2.05 (2.43)	2.24 (2.39)	2.09 (2.32)	2.36 (2.70)	.002†

Note: Bayesian Estimates of Group Means indicates statistical significance within-subject differences for total sub-sample population‡. General linear model one-way repeated measures ANOVA indicates significant difference for within-subject differences in females and males using Greenhouse-Geisser correction†. Means in the rows denoted by the same subscript[a] are significantly different from each other as indicated by a Bonferroni post hoc test.

4.6 Discussion

Cannabis consumption continues to be prevalent among EA in Canada. EA are disproportionately vulnerable to substance risk and misuse in the face of adverse societal and environment conditions. This study sheds light on the impact of policy amendments, and public health concerns, on cannabis consumption frequency patterns of EAs. Specifically, the recreational legalization of cannabis consumption in Canada, the EVALI epidemic, and continuously evolving COVID-19 pandemic. Our findings suggest that among EA, these developments exert an impact on smoking and vaping patterns of cannabis consumption by increasing rather than decreasing consumption frequency. In addition, an increase in average smoking and vaping frequency was seen before and after each time period for males and females.

Changes in average frequency demonstrated that users are likely to show incremental and gradual changes in frequency patterns than drastic changes when influenced by external factors. In addition, inconsistencies in average frequency of use over time, in which we found the average frequency of use to be lower at the start of each new event relative to the end of the previous one, may reflect patterns of consumption among non-frequent recreational users, in which occasional reporting of increased frequency are likely to be elicited by specific personal and lifestyle events. Thus, gradual changes in frequency and inconsistencies in average frequency may indicate that EA are likely to engage in opportunistic experiences within their environment in smoking or vaping cannabis (i.e., with friends, during parties) (Mostaghim & Hathaway, 2013), although not maintain a consistent and sustained increase in consumption over time.

A notable finding is that cannabis users smoking at a higher frequency (weekly or daily) may increase their use, and thus demonstrate an easier transition to dependency, especially in the face of changing social and environmental contexts. In fact, individuals using on a daily or

almost daily basis are identified to be more at risk for dependency (Rotermann, 2019). In addition, our results suggest that frequent users, including those that smoke or vape cannabis daily may sustain their consumption despite public health risks. Given that we found more occasional vapers and smokers (i.e., using less than once a month) decrease their consumption after COVID-19 suggests that they may have limited motivations for use in their social environment, specifically due to the social restrictions of the pandemic, living at home with parents, and in less contexts conducive to cannabis use (e.g., parties, school). These findings were also seen in a study by Van Laar et al. (2020), which found that occasional users (using a few times per month) were more likely to reduce their use, whereas individuals that reported a higher frequency (almost daily) sustained this use after the lockdown measures in the Netherlands (Van Laar et al., 2020). Thus, individuals that smoke or vape occasionally may transition easier to using occasionally than those using frequently, who have a greater difficulty in transitioning to cessation and remediation due to developed dependence (Van der Pol et al., 2013).

Our results also suggest that a high proportion of cannabis users that did not smoke or vape before legalization, experimented with vaping and smoking after legalization. These findings support the general consensus that the federal policy change may have led to an increase in prevalence of cannabis consumption (Rotermann, 2020). Findings also indicate a significant increase in average smoking and vaping frequency among males and females before and after legalization. These findings complement a study by Sandhu et al. (2019), which found that among Canadians 15 years and older, 18.5% would increase use/initiate following legalization. In addition, another study found a 20% increase in the prevalence of college students initiating cannabis use living in the state of Colorado after legalization (Parnes et al., 2018).

Increases in frequency following legalization may indicate lower perceived risks, especially among females (Hathaway et al., 2018; Harris-Lane et al., 2020). After legalization the proportion of females (50%) that increased their frequency in consumption was higher than the proportion of males (43%). As such, gender may potentially change behavior, modulated by environmental changes to cannabis use trajectories (Greaves & Hemsing, 2020). Our findings are consistent with evidence showing that females consistently report lower cannabis use rates than males (Callaghan et al., 2019; Cuttler & Mischley, 2016). On the other hand, increases in average frequency of both vaping and smoking over time, coincides with research suggesting a narrowing gender gap with females reporting higher use rates than in the past (Greaves & Hemsing, 2020; Rotermann 2020). These findings may support the hypothesis that females transition faster from initiation with lower consumption patterns to regular and increased use (Cooper & Haney, 2014).

Our study sample consisted of a high proportion of dual users. This may carry a risk for increased frequency of use and dependence. Evidence suggests that among college-aged cannabis users, initiating vaping increased overall frequency patterns of cannabis use over time, and thus the risk of dependence, as vaping becomes an additive rather than a replacement behavior (Cassidy et al., 2018). Moreover, increases in average frequency of vaping before and after EVALI may reflect the limited awareness of the EVALI epidemic in Canada, where lower infection rates have been reported (Government of Canada, 2020). Contrary to our expectations, the percentage of users that increased their vaping frequency was higher than the percentage of users that decreased their frequency. These findings contradict health belief theories, which would expect individuals to make healthier behavior changes due to perceived risk of a particular health outcome (Rosenstock, 1994). In contrast, recent evidence suggests that the ‘safety’

narrative surrounding vaping products is changing, and may influence current users (ages 15-24) to quit vaping (Kreslake et al., 2020). However, studies have mainly focused on perceptions of using vaping products after EVALI among tobacco smokers, or adult patients (Morgan et al., 2021; Patel et al., 2020). This underscores the necessity in examining changes in consumption behaviors of cannabis users that vape or smoke, as most EVALI cases have been linked to THC oils (Ellington et al., 2020).

To our knowledge, there are no studies that have examined the impact of EVALI on consumption patterns of cannabis vaping in Canada. It may be reasonable to assume that due to limited knowledge and awareness, this may have led to underestimation of risk and severity associated with EVALI, and overall an increase in average frequency of vaping found in this study. In addition, it is important to note that this epidemic has largely been attributable to "black market" vaping devices, so that may have also influenced perceptions and consumption practices, given that the legal market in Canada has expanded and become more stringent since legalization (Rotermann, 2019).

Moreover, EVALI may not affect smoking consumption patterns as much as it may negatively influence vaping frequency. However, as most vapers tend to be dual users (vapers and smokers) (Lee et al., 2016; Jones et al., 2016), it may influence users to transition back to exclusively smoking. Since levels of perceived risk have been linked to modification of health-related behaviors (Lin et al., 2020; Rosenstock, 1994), studies should examine the effect of the ongoing EVALI epidemic on the evolution of vaping cannabis product use among vulnerable populations in relation to perceived risk factors.

Given the pathology and respiratory nature of the virus, early research and news from the media advising public health precautions, suggested reducing or quitting smoking and using any

methods to inhale substances (e.g., nicotine, cannabis etc.), in efforts to decrease risk-factors that may exacerbate COVID-19-related symptoms (Borgonhi et al., 2021; Yu, 2020). Despite these precautions, our study found an increase in average frequency of consumption after the pandemic. This may reflect low perceptions of risk associated with COVID-19 infection among EA. Alternatively, the benefits of using cannabis to mitigate or manage adverse mental health outcomes associated with the pandemic, and using with peers may outweigh the potential risks of respiratory health complications associated with infection for these individuals.

This study is generally in line with recent results from other online surveys that have found a significant increase in the number of days cannabis was used after the pandemic among female adolescents (14 to 18 years) in Canada (Dumas et al., 2020), and adult (mean age 32.7 ± 12.0) cannabis users in the Netherlands (Van Laar et al., 2020). Specifically, the study by Van Laar et al. (2020) found that the proportion of young adults (16-24) increasing their use was higher than the proportion of older adults (≥35), 51.6% and 23.1%, respectively. In addition, a higher proportion of women than men (50.4% vs 36.5%) used cannabis more often since the lockdown. Women reported stress and mental health factors as main reasons for increased consumption than men (Van Laar et al., 2020). These findings support the importance of examining changes in cannabis consumption patterns among age and sex-specific groups, who may be particularly vulnerable to the uncertainties and instability of the pandemic (Germani et al., 2020).

Strengths and Limitations

This study contributes to filling the much-needed research gap in examining the distribution of cannabis consumption by frequency of vaping and smoking among cannabis users in Canada in relation to sex. In addition, this naturalistic study helps to understand the

implications of on-going public health concerns on consumption patterns among vulnerable populations, and provides a unique approach to examining frequency of smoking and vaping over time in a sample of EA. Nonetheless, there are a number of limitations to this study. Data in relation to cannabis frequency of inhalation routes of consumption were self-reported, and specifically focused on the consumption trends of a relatively small sample of EA in Canada. The cross-sectional exploratory design of this study prevents determination of causality. In addition, this study also examined retrospective analysis of smoking and vaping frequency, thus introducing recall bias, which may have limited the accuracy of the changes over time. However, among youth, retrospective substance measures recalled even one year later have produced good predictive validity (Dumas et al., 2020; Collins et al., 1985), and recall estimation is predictive when cannabis users report consistent and frequent patterns of use (Goodman et al., 2019). In addition, limited data were missing, suggesting that participants were likely able to recall frequency patterns and subsequent changes.

Since many users were not aware of EVALI, changes in frequency may be a result of changes over time, and not specifically reflective of being aware of the risks associated with the EVALI epidemic. Future research should indicate the predictors of change associated with frequency of both smoking and vaping, and other critical measures, including quantity of cannabis forms used across a larger representative population of cannabis users. This may facilitate the understanding of individual-level characteristics associated with patterns of consumption during a pandemic, and individual assessment of different motives for use.

4.7 Conclusion

This study suggests that external factors may facilitate increases in cannabis consumption in EA, as a result of deviations in political, social, and natural contexts. Monitoring of health outcomes and infection should be of concern for this vulnerable population, given the respiratory health-risks associated with COVID-19. Ongoing monitoring will be required to determine whether changes (or alternatively, stability) in user status observed in the period immediately following the implementation of *legalization*, EVALI, and COVID-19 pandemic are temporary (and related to a desire to try a previously illegal substance) or the beginning of longer-term trends in relation to sex-specific outcomes. Further, understanding the predictors in relation to various environmental and social contexts of emerging adult substance use may provide new targets for preventive intervention and cessation programs, as well as inform long-term health risks.

References for Chapter 4

Ames, M. E., Leadbeater, B. J., Merrin, G. J., and Thompson, K. (2020). Patterns of marijuana use and physical health indicators among Canadian youth. International journal of psychology, 55(1), 1-12. doi.org/10.1002/ijop.12549

Arnett, J. J., Žukauskienė, R., and Sugimura, K. (2014). The new life stage of emerging adulthood at ages 18–29 years: implications for mental health. The Lancet Psychiatry, 1(7), 569–576. doi: 10.1016/s2215-0366(14)00080-7

Aberegg, S. K., Cirulis, M. M., Maddock, S. D., Freeman, A., Keenan, L. M., Pirozzi, C. S., ... & Callahan, S. J. (2020). Clinical, Bronchoscopic, and Imaging Findings of e-Cigarette, or Vaping, Product Use–Associated Lung Injury Among Patients Treated at an Academic Medical Center. *JAMA Network Open*, *3*(11), e2019176-e2019176.

Beard, E., Dienes, Z., Muirhead, C., and West, R. (2016). Using Bayes factors for testing hypotheses about intervention effectiveness in addictions research. *Addiction (Abingdon, England)*, *111*(12), 2230–2247. https://doi.org/10.1111/add.13501

Borgonhi, E. M., Volpatto, V. L., Ornell, F., Rabelo-da-Ponte, F. D., and Kessler, F. H. P. (2021). Multiple clinical risks for cannabis users during the COVID-19 pandemic. *Addiction Science and Clinical Practice*, *16*(1), 1-4. https://doi.org/10.1186/s13722-021-00214-0

Callaghan, R. C., Sanches, M., Benny, C., Stockwell, T., Sherk, A., and Kish, S. J. (2019). Who consumes most of the cannabis in Canada? Profiles of cannabis consumption by quantity. *Drug and alcohol dependence*, *205*, 107587. https://doi.org/10.1016/j.drugalcdep.2019.107587

Cassidy, R. N., Meisel, M. K., Diguiseppi, G., Balestrieri, S., and Barnett, N. P. (2018). Initiation of vaporizing cannabis: Individual and social network predictors in a longitudinal study of young adults. *Drug and Alcohol Dependence*, 188, 334–340. doi: 10.1016/j.drugalcdep.2018.04.014

Collins, L. M., Graham, J. W., Hansen, W. B., and Johnson, C. A. (1985). Agreement between retrospective accounts of substance use and earlier reported substance use. *Applied Psychological Measurement*, *9*(3), 301-309. https://doi.org/10.1177/014662168500900308

Cooper, Z. D., and Haney, M. (2014). Investigation of sex-dependent effects of cannabis in daily cannabis smokers. *Drug and alcohol dependence*, *136*, 85–91. https://doi.org/10.1016/j.drugalcdep.2013.12.013

Cuttler, C., Mischley, L. K., and Sexton, M. (2016). Sex Differences in Cannabis Use and Effects: A Cross-Sectional Survey of Cannabis Users. Cannabis and cannabinoid research, 1(1), 166–175. doi:10.1089/can.2016.0010

Dubey, M. J., Ghosh, R., Chatterjee, S., Biswas, P., Chatterjee, S., and Dubey, S.

(2020). COVID-19 and addiction. *Diabetes and metabolic syndrome*, *14*(5), 817–823. https://doi.org/10.1016/j.dsx.2020.06.008

Dumas, T. M., Ellis, W., and Litt, D. M. (2020). What does adolescent substance use look like during the COVID-19 pandemic? Examining changes in frequency, social contexts, and pandemic-related predictors. *Journal of Adolescent Health*, *67*(3), 354-361. https://doi.org/10.1016/j.jadohealth.2020.06.018

Ellington, S., Salvatore, P. P., Ko, J., Danielson, M., Kim, L., Cyrus, A., ... and Wallace, B. M. (2020). Update: product, substance-use, and demographic characteristics of hospitalized patients in a nationwide outbreak of e-cigarette, or vaping, product use–associated lung injury—United States, August 2019–January 2020. *Morbidity and Mortality Weekly Report*, *69*(2), 44.

Esterwood, E., and Saeed, S. A. (2020). Past Epidemics, Natural Disasters, COVID19, and Mental Health: Learning from History as we Deal with the Present and Prepare for the Future. *The Psychiatric quarterly*, *91*(4), 1121–1133. https://doi.org/10.1007/s11126-020-09808-4

Follert, J. (2020, June 1). Ontario Tech student wants to know: Has pandemic changed your cannabis use? Retrieved from https://www.durhamregion.com/news-story/10000838-ontario-tech-student-wants-to-know-has-pandemic-changed-your-cannabisuse-/?fbclid=iwar0djx0wrglvzfppcrh62dekvt8ssbfvpo9zwiokgioa4tjsouvafnftqla#.XtZuZhu-J-I.facebook

Gaiha, S. M., Cheng, J., and Halpern-Felsher, B. (2020). Association between youth smoking, electronic cigarette use, and COVID-19. *Journal of adolescent health*, *67*(4), 519-523. https://doi.org/10.1016/j.jadohealth.2020.07.002

Germani, A., Buratta, L., Delvecchio, E., Gizzi, G., and Mazzeschi, C. (2020). Anxiety severity, perceived risk of COVID-19 and individual functioning in emerging adults facing the pandemic. *Frontiers in psychology*, *11*. doi: 10.3389/fpsyg.2020.567505

Goodman, S., Leos-Toro, C., and Hammond, D. (2019). Methods to Assess Cannabis Consumption in Population Surveys: Results of Cognitive Interviewing. Qualitative Health Research, 29(10), 1474-1482. doi:10.1177/1049732318820523

Government of Canada (2021). *Vaping-associated lung illness*. From: https://www.canada.ca/en/public-health/services/diseases/vaping-pulmonary-illness.html, Accessed date: 19 April 2021.

Greaves, L., and Hemsing, N. (2020). Sex and gender interactions on the use and impact of recreational cannabis. *International journal of environmental research and public health*, *17*(2), 509. https://doi.org/10.3390/ijerph17020509

Halladay, J., Petker, T., Fein, A., Munn, C., and Mackillop, J. (2018). Brief interventions for cannabis use in emerging adults: Protocol for a systematic review, meta-analysis, and evidence map. Systematic Reviews, 7(1). doi:10.1186/s13643-018-0772-z

Hancox, R. J., Shin, H. H., Gray, A. R., Poulton, R., and Sears, M. R. (2015). Effects of

quitting cannabis on respiratory symptoms. *European Respiratory Journal*, *46*(1), 80-87. doi: 10.1183/09031936.00034515

Harris-Lane, L., Winters, E., and Harris, N. (2020). Emerging Adult Perceptions of Cannabis Use Based on Age and Sex of User. Emerging Adulthood, 2167696820930862. https://doi-org.uproxy.library.dc-uoit.ca/10.1177/2167696820930862

Hathaway, A. D., Mostaghim, A., Erickson, P. G., Kolar, K., and Osborne, G. (2018). "It's Really No Big Deal": The Role of Social Supply Networks in Normalizing Use of Cannabis by Students at Canadian Universities. *Deviant Behavior*, 39(12), 1672–1680. doi: 10.1080/01639625.2017.1411047

Hyman, S. M., and Sinha, R. (2009). Stress-related factors in cannabis use and misuse: implications for prevention and treatment. *Journal of substance abuse treatment*, *36*(4), 400–413. https://doi.org/10.1016/j.jsat.2008.08.005

Imtiaz, S., Wells, S., Rehm, J., Hamilton, H. A., Nigatu, Y. T., Wickens, C. M., ... and Elton-Marshall, T. (2021). Cannabis Use During the COVID-19 Pandemic in Canada: A Repeated Cross-sectional Study. *Journal of Addiction Medicine*. doi: 10.1097/ADM.0000000000000798

Jeffreys, H. (1961). *Theory of Probability, 3rd Edn*. Oxford, UK: Oxford University Press.

Jones, C.B., Hill, M.L., Pardini, D.A., Meier, M.H. (2016). Prevalence and correlates of vaping cannabis in a sample of young adults. Psychol. Addict. Behav. 30, 915–921. http://dx.doi.org/10.1037/adb0000217

Kreslake, J. M., Diaz, M. C., Shinaba, M., Vallone, D. M., and Hair, E. C. (2021). Youth and young adult risk perceptions and behaviours in response to an outbreak of e-cigarette/vaping-associated lung injury (EVALI) in the USA. *Tobacco Control*. http://dx.doi.org/10.1136/tobaccocontrol-2020-056090

Lee, D. C., Crosier, B. S., Borodovsky, J. T., Sargent, J. D., and Budney, A. J. (2016). Online survey characterizing vaporizer use among cannabis users. Drug and Alcohol Dependence, 159, 227–233. doi: 10.1016/j.drugalcdep.2015.12.020

Lee, C. M., Neighbors, C., and Woods, B. A. (2007). Marijuana motives: young adults' reasons for using marijuana. *Addictive behaviors*, *32*(7), 1384–1394. https://doi.org/10.1016/j.addbeh.2006.09.010

Lee, M. D., and Wagenmakers, E. J. (2014). *Bayesian Cognitive Modeling: A Practical Course*. Cambridge: Cambridge University Press.

Leos-Toro, C., Rynard, V., Murnaghan, D., MacDonald, J. A., and Hammond, D. (2019). Trends in cannabis use over time among Canadian youth: 2004–2014. *Preventive medicine*, *118*, 30-37. https://doi.org/10.1016/j.ypmed.2018.10.002Morgan, J.

C., Silver, N., and Cappella, J. N. (2021). How did beliefs and perceptions about e-cigarettes change after national news coverage of the EVALI outbreak?. *PLOS ONE*, *16*(4), e0250908. doi: https://doi.org/10.1371/journal.pone.0250908

Ornell, F., Moura, H. F., Scherer, J. N., Pechansky, F., Kessler, F. H. P., and von Diemen, L. (2020). The COVID-19 pandemic and its impact on substance use: Implications for prevention and treatment. *Psychiatry research*, *289*, 113096. doi:10.1016/j.psychres.2020.113096.

Parnes, J. E., Smith, J. K., and Conner, B. T. (2018). Reefer madness or much ado about nothing? Cannabis legalization outcomes among young adults in the United States. International Journal of Drug Policy, 56, 116–120. doi: 10.1016/j.drugpo.2018.03.011

Rotermann, M. (2020). What has changed since cannabis was legalized. *Health Rep*, *31*(2), 11-20. doi: https://www.doi.org/10.25318/82-003-x202000200002-eng

Sandhu, H. S., Anderson, L. N., and Busse, J. W. (2019). Characteristics of Canadians likely to try or increase cannabis use following legalization for nonmedical purposes: a cross-sectional study. *CMAJ open*, *7*(2), E399. doi: 10.9778/cmajo.20190008

Stone, A. L., Becker, L. G., Huber, A. M., and Catalano, R. F. (2012). Review of risk and protective factors of substance use and problem use in emerging adulthood. *Addictive Behaviors*, 37(7), 747–775. doi:10.1016/j.addbeh.2012.02.014

Sohrabi C, Alsafi Z, O'Neill N, Khan M, Kerwan A, Al Jabir A, Iosifidis C, Agha R. World Health Organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19). *Int J Surg*. 2020;76:71–6. doi:10.1016/j.ijsu.2020.02.034.

Taylor, D. R., Poulton, R., Moffitt, T. E., Ramankutty, P., and Sears, M. R. (2000). The respiratory effects of cannabis dependence in young adults. *Addiction*, 95(11), 1669–1677. doi: 10.1046/j.1360-0443.2000.951116697.x

Van Laar, M. W., Oomen, P. E., van Miltenburg, C., Vercoulen, E., Freeman, T. P., and Hall, W. D. (2020). Cannabis and COVID-19: Reasons for Concern. *Frontiers in psychiatry*, *11*, 601653. https://doi.org/10.3389/fpsyt.2020.601653

Yang, X. Y., Gong, R. N., Sassine, S., Morsa, M., Tchogna, A. S., Drouin, O., ... & Jantchou, P. (2020). Risk Perception of COVID-19 Infection and Adherence to Preventive Measures among Adolescents and Young Adults. *Children*, *7*(12), 311.

Yu, G. (2020, March 20). How smoking, vaping and drug use might increase risks from Covid-19. CNN Health. Retrieved from: https://www.cnn.com/2020/03/20/health/coronavirus-vaping-drugs/index.html

Chapter 5. Manuscript 2

Changes in quantity measures of various forms of cannabis consumption among emerging adults in Canada in relation to policy and public health developments

Susan Yousufzai [a]*, Mika Nonoyama[a], Adam Cole[a], and Caroline Barakat[a]

[a]*Faculty of Health Sciences, Ontario Tech University, Oshawa, Canada*

Submitted to: *Journal of Cannabis Research*

5.1 Abstract

Background: Loosening legal restrictions may impact population-level cannabis use by changing patterns of use over time. There is limited research examining changes in quantities of various forms of smoked/vaped cannabis (i.e., dried herb, oils, concentrates) among high consumers, including emerging adults (EA; 18 to 29) in Canada. This information is particularly relevant in the current context of emerging cannabis behaviors related to political amendments, vaping-related lung illnesses (EVALI), and unprecedented pandemics in youth substance use. **Objective:** We investigated the impact of legalizing recreational cannabis use in Canada, the EVALI epidemic, and corona virus disease (COVID-19) pandemic on cannabis quantity smoked/vaped of various forms in relation to sex. **Methods:** EA living in Canada self-reported the quantity of dried herb, hash/hashish, concentrates, and joint size used in grams, and the number of joints and vaping cartridges over time in relation to three consecutive developments: pre-legalization, post-legalization; pre-EVALI epidemic, post-EVALI epidemic; pre-COVID-19 pandemic; post-COVID-19 pandemic. **Results:** An increasing trend was observed in the average quantity of cannabis forms used over time, specifically for dried herb, joint size, number of joints, and vaping cartridges. Males consumed higher quantities of all cannabis forms than females. More males than females reported using concentrates ($p<0.05$). **Conclusions:** These findings reveal unique aspects of the amount smoked/vaped of various cannabis forms in relation to sex, and provides preliminary evidence of cannabis consumption behaviors in relation to changing social and cultural contexts. Future research should continue to monitor the amount of cannabis consumed in all its forms, and examine its health effects in vulnerable subpopulations.

Keywords: cannabis; emerging adults; quantity; COVID-19; EVALI; legalization

5.2 Introduction

In Canada, cannabis consumption rates are characterized by marked differences in relation to age and sex (Rotermann & Macdonald, 2018; Leos-Toro et al., 2018). For example, the prevalence of daily or almost daily consumption is higher (12.5%) among EA (18 to 24-year-olds) than among 45 to 64-year olds (4.8%) (Rotermann, 2019). In relation to sex, 7.6% of males compared to 4.5% of females report using cannabis daily or almost daily (Rotermann, 2019). In addition, recent evidence shows that almost a third (65.4%) of all cannabis products in Canada is consumed by a relatively small population (10.2%) of very heavy cannabis users. This was mostly accounted for by the younger age group (15 to 34), and males in particular (Callaghan et al., 2019). These findings suggest that examining cannabis consumption patterns and related health implications among frequent and heavy consumers (i.e., EA) in relation to sex may be critical for addressing public health outcomes.

Contrary to its widespread permissive use and presumptions as a 'benign' substance among EA (Harris-Lane et al., 2020; Mostaghim & Hathaway, 2013), cannabis-related harms are evident when used regularly or heavily, and when initiated at a young age (Asbridge et al., 2014; Iede et al., 2017; Roterman, 2019). For example, earlier onset and higher frequency – particularly weekly or daily patterns - of cannabis use puts individuals at elevated risk for dependency (Rotermann, 2019; Van Der Pol et al., 2013; Zeisser et al., 2012). However, frequency patterns alone may not reflect the extent of risk (Zeisser et al., 2012). Among users reporting daily use, dependency risk is differentiated by the actual quantity of use (i.e., number of joints smoked per week) (Looby & Earleywine, 2007), suggesting that quantity is a critical measure of cannabis-related risks. However, a clear understanding of cannabis-related behaviors, harms and effects are hindered by the paucity of studies examining various methods of

consumption, and measuring quantity of consumption in relation to various cannabis forms (Callaghan et al., 2020; Leos-Toro et al., 2020; Rotermann, 2019; Zeisser et al., 2012).

The complexity of measuring cannabis-related effects and risks are further complicated by sex-specific neurobiological mechanisms, gender-specific consumption differences, and motives for use. Nascent evidence suggests higher sensitivity to cannabis among females, and problematic use, although males' development of a cannabis use disorder (CUD) is more reliant on gender and social norms that influence earlier initiation, accessibility and acceptability (Greaves & Hemsing 2020).

Emerging trends of cannabis consumption behaviors and diversified profiles associated with policy liberalization warrants research to examine quantity of cannabis used, as they vary across product and modes of administration (Callaghan et al., 2020; Russel et al., 2018). Different modes of administration, such as joints, blunts, pipes, bongs, dabs rigs, and vaporizers, are used for different forms and can vary with the quantity used per dose and the potency of Δ-9-tetrahydrocannabinol (THC) (Russel et a., 2018; Gloss, 2015). While smoking traditional forms of cannabis such as dried herb remains the most common method of consumption, concentrates (e.g., "shatter", "budder"), oils and hash, are becoming increasingly popular (Callaghan et al., 2020; Rotermann, 2019). Simultaneously, novel iterations of vaping devices in addition to smoking (dual use), are being used to vape these diverse array of cannabis forms (Chand et al., 2020; Lee et al., 2016). Indeed, vaping 'carts' is viewed as a convenient and appealing method of consumption, especially among EA (Jones et al., 2016). However, vaping may pose significant health risks for cannabis users. In fact, 82% of 'electronic cigarette or vaping product associated lung injury' (EVALI) cases in the USA have been caused by a compound mixture of THC vaping-oil and vitamin-E-acetate. 78% of these cases report informal sources (friends, online or

dealers) (Ellington et al., 2020), which suggests that legally purchased products may also present unknown effects.

Some evidence suggests that there have been declines in e-cigarette sales following news of the EVALI outbreak in the USA (September 2019-January 2020), and has influenced cessation intentions of vaping (Kreslake et al., 2021). However, there are no studies examining subsequent changes in patterns of consumption. Accordingly, these findings warrant research that examines how EVALI may influence cannabis-specific vaping and smoking consumption, even in countries such as Canada that have witnessed lesser EVALI cases (Government of Canada, 2020). In addition, the lack of understanding about the health effects of various constituents when aspirated provides significant reason for continuous monitoring of consumption behaviors (Braymiller et al., 2020; King et al., 2020).

In addition, the bi-directional relationship between COVID-19 and substance misuse has been a key concern of the pandemic, especially due to increased vulnerability to adverse respiratory consequences associated with smoking or vaping (Borgonhi et al., 2021; Cherkasova, 2020). Emerging evidence suggests increases in frequency (days used) among adolescent girls in particular (Dumas et al., 2020), and more EA smoking a greater number of joints on a daily basis in other regions (Van Laar et al., 2020). Studies have not addressed the impact on quantity of various forms of cannabis used (e.g., herb, hash, concentrates, oil). Changes in consumption may be unique for EA in Canada, who have legal access to a diverse range of cannabis products. In addition, during the pandemic, EA may be more prone to use cannabis to allay negative feelings, often noted as 'coping-oriented reasons' that increase the risk of substance dependence (Van Der Pol et al., 2013). Moreover, given that EA use cannabis as a social cohesion tool, and sharing

joints and vaping devices is common practice among cannabis users (Van Laar et al., 2020), social restrictions may affect individual quantity of consumption.

The aim of this study was to examine if there was a change in self-reported quantity of cannabis consumption forms (dried herb, concentrates, hash, and vaping liquid/oil) following the legalization of recreational cannabis use in Canada, the EVALI epidemic, and COVID-19 pandemic, among male and female EA in Canada.

5.3 Methods

Study design and ethical approval

This is a cross-sectional exploratory study. Ethics approval for this research was received from the Ontario Tech University Research Ethics Board on May 4, 2020 [REB#15880].

Participants and recruitment

Convenience sampling was used to recruit participants 18 to 29 years old through social media platforms (Facebook and Twitter) and from Ontario Tech University. An online survey was completed by 312 cannabis users across Canada. Recruitment and data collection occurred from May 4, 2020 to August 31, 2020. Respondents were identified as cannabis users if they reported smoking and / or vaping in the last 12 months. Results of 343 individuals were reviewed, of which 312 were eligible. Respondent data were excluded if they: accessed the survey but did not answer any questions regarding the inclusion and exclusion criteria (n=3), were not 18-29 years old (n=11), did not smoke or vape cannabis in the last 12 months (n=13), or did not consent (n = 3). Online consent was required from participants before obtaining access to survey.

Measures

Questions pertaining to forms and quantity measures of cannabis forms used were derived and modified from the *International Cannabis Policy Study* (ICPS) (Hammond et al., 2018), and *Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory* (DFAQ-CU) (Cuttler and Spradlin, 2017).

Assessment of cannabis quantity forms included: (1) dried herb; (2) hash; (2) concentrates; and (3) cannabis oil/vape juice. For each form of cannabis, participants were asked to report if they considered it as one primary form that they used predominantly or most often (DFAQ-CU): “Do you consider dried herb as one ‘primary’ form of cannabis that you use?”; Do you consider Hash/Hashish as one 'primary' form of cannabis that you use?”; “Do you consider cannabis concentrates (e.g., Wax, Shatter, Butane Hash Oil, Dabs) as one 'primary' form of cannabis that you use?”; “Do you consider cannabis oil/vape juice as one 'primary' form of cannabis that you use?”. Participants were given response options: “yes” or “no”. Answering “yes” directed participants to the specific form used and corresponding quantity measures. Participants may have chosen more than one form to report (Figure 5.1).

For herb quantity, participants were able to choose the method to quantify their use, by choosing to report the amount of dried herb used in grams or the equivalent joint size in grams and number of joints personally smoked. Participants were queried: “Is it easier for you to tell us the joint size or the amount of dried herb (e.g., grams or ounces) you use?”. Images of herb quantities and joint sizes with corresponding measurements were provided for reference in the survey to help quantify the amount used (derived from Hammond et al., 2018).

For each primary form selected, participants reported retrospectively the quantity of the primary cannabis form used before and after each event: legalization of recreational cannabis use

in Canada (approximately October, 2018), the declaration of EVALI (approximately November 2019), and since the implementation of the COVID-19 pandemic (approximately March, 2020). The quantity of each form consumed before and after each event were based on the following questions: “On the days you use(d) dried herb, about how much did you personally use?”; “On the days you use(d) joints, what joint size is closest to the size you normally smoke(d)?”; “On the days you use(d) joint(s), how many did you smoke?”; “On the days you use(d) Hash/Hashish how much did you personally use?”; “On the days you use(d) concentrates how much did you personally use?”. For vaping liquid/oil, participants were asked: “What size vaping cartridge do you 'primarily' use?”, and “How many vape cartridge(s) or refill(s) did you use in a month?”. Measuring vaping quantity by the number of cartridges over a long timeframe than a day is found to be effective in measuring consumption. Therefore, consumption of vaping was examined by average of vaping cartridges used in a month. Evidence shows most respondents prefer to report the number of cartridges or tank refills (51%), and fewer users finish 1 cartridge/tank in a day (Wong et al., 2019). Data for the size of vaping cartridge used was omitted due to limited responses to the open-ended question.

Herb quantity was based on the amount measured in grams (0, less than 1/8g, 1/8g, 1/4g, 1/2g, 3/4g, 1g, 2g, 3g, 1/8 ounce, ¼ ounce, more than ¼ ounce). Joint size was measured in grams (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2) and the number of joints (i.e., 0, ¼ (0.25), ½ (0.5), ¾ (0.75), 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, More than 10). Hash and concentrate quantity were also measured in grams (0, less than 0.5, 0.5, 1, 2, 3, 4, 5, 6, 7, more than 7). Reference images were provided to quantify 1 gram of hash and concentrate (derived from Hammond et al., 2018). Vaping cannabis oil/juice was determined based on the number of vape cartridges/refills used in a usual month [0,

less than half of a cartridge (0.25), ½ (0.5), 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, More than 10]. Numeric assumptions were inputted for options “less than” or “More than” the amount indicated.

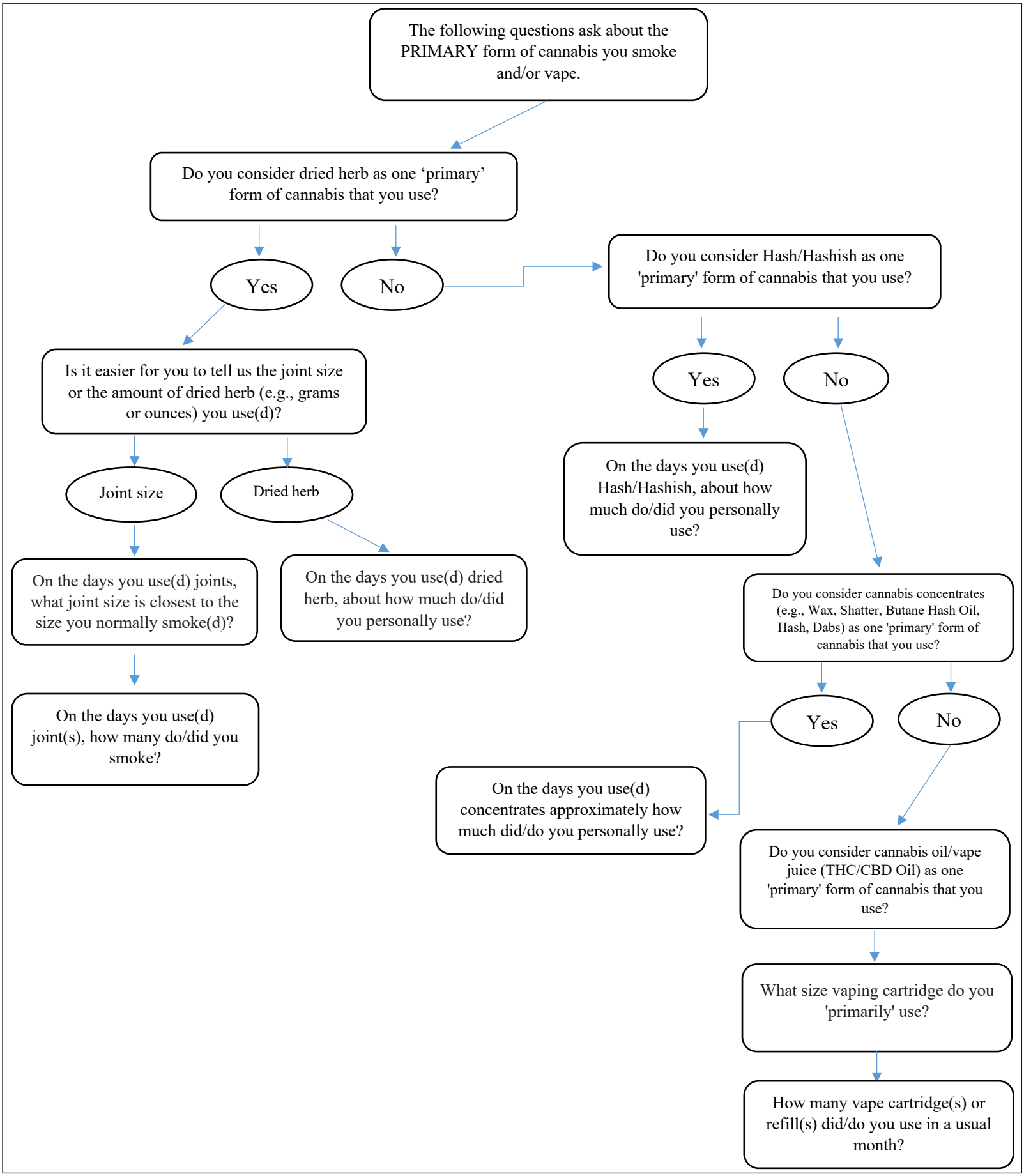

The following questions ask about the PRIMARY form of cannabis you smoke and/or vape.
Do you consider dried herb as one 'primary' form of cannabis that you use?
Yes
No
Do you consider Hash/Hashish as one 'primary' form of cannabis that you use?
Is it easier for you to tell us the joint size or the amount of dried herb (e.g., grams or ounces) you use(d)?
Yes
No
On the days you use(d) Hash/Hashish, about how much do/did you personally use?
Joint size
Dried herb
On the days you use(d) joints, what joint size is closest to the size you normally smoke(d)?
On the days you use(d) dried herb, about how much do/did you personally use?
Do you consider cannabis concentrates (e.g., Wax, Shatter, Butane Hash Oil, Hash, Dabs) as one 'primary' form of cannabis that you use?
On the days you use(d) joint(s), how many do/did you smoke?
Yes
No
On the days you use(d) concentrates approximately how much did/do you personally use?
Do you consider cannabis oil/vape juice (THC/CBD Oil) as one 'primary' form of cannabis that you use?
What size vaping cartridge do you 'primarily' use?
How many vape cartridge(s) or refill(s) did/do you use in a usual month?

Figure 5.1. Survey outline of questions used for reporting quantity of cannabis forms used.

5.4 Data analysis

Data were analyzed using SPSS v 27 (IBM SPSS Statistics 27 ©). Chi-square tests were used to analyze frequencies and differences of the forms of cannabis used by sex. One-way repeated measures analysis of variances (ANOVAs) using Bayesian analysis were conducted to evaluate the effects of the six time periods that are marked by major legislative and public health developments (pre-legalization, post-legalization; pre-EVALI, post-EVALI; pre-COVID-19, post-COVID-19), on the six dependent continuous variables (quantity of the cannabis forms [herb, joint size/quantity, vaping cartridges, hash, and concentrate]). The Bayes factor was determined to indicate statistical significance ($p < 0.05$) using the estimation method for Rouder's mixed design. Bayes factor test yields a *BF* quantifying how well the alternative hypothesis (H_1) predicts the empirical data relative to the null hypothesis (H_0) (Jeffreys, 1961; Lee and Wagenmakers, 2014). The strength of the evidence relies on BFs above 3 for the alternative hypothesis and below 0.33 for the null hypothesis, while values between approximately ⅓ and 3 indicate that the data are insensitive (Beard et al., 2016). Analyses stratified by sex for females and males were conducted using general linear model repeated measures ANOVA to describe differences in quantity of cannabis forms for the six outcome measures. Post-hoc comparisons using the Bonferroni correction were conducted to determine significant between-subject differences for each time interval and outcome.

5.5 Results

The final sample included 312 cannabis users (189 female, 123 male). The mean age of the sample was 23 years. The majority of participants were of Caucasian/White descent (males: 50%, females: 62%). The most popular form of cannabis used as the primary form was herb for males and females (91%), followed by cannabis vaping oil/e-liquid, which was endorsed by 15%

of males and 15% of females. More males (15%) than females (7%) reported using cannabis concentrates as the primary form (χ^2 (1) = 5.02, p<0.05). Hash was indicated as the least primary form used by males (3%) and females (5%).

Changes in quantity of cannabis consumption forms

There was a statistically significant difference in herb quantity over time across the various events (*BF* (14) = 4.496), p<0.001, showing strong evidence for an effect on quantity of herb used over time in the sample population (*Bf* > 3) (Table 5.1). Analyses separated by sex indicated no significant difference for males (*F* (2.35, 176.405) = .939, p = .41), but a statistically significant difference for females (*F* (2.13, 212.941) = 5.585, p =.004), which indicated an increasing trend over time. Post-hoc comparisons revealed that a significant increase was evident from only before and after legalization for females (p = 0.005), in which herb quantity increased from an average of almost 0.75 grams to at least 1 gram personally used on a typical day. Over time, among females in our sample, use of herbs almost doubled from 0.67 to 1.2g in females from before legalization through to after the COVID-19 pandemic.

Joint quantity and joint size significantly differed over time (*BF* (14) = 65.776, p<0.001) (Table 4). Strong evidence in support of the experimental hypothesis (H_1) showing an effect on joint quantity over time was indicated (*Bf* > 3). Analyses separated by sex showed that there was a significant increase in joint quantity for males (*F* (2.25, 58.521) = 3.05, p = .049 and for females (*F* (2.4, 134.6) = 4.902, p =.006). The average number of joints smoked on a typical day by females was highest post the pandemic period (M=.86). In relation to joint size, the overall results indicate no evidence for an effect on joint size in relation to the events (*BF* (14) = .903, p<0.001). Although analyses stratified by sex showed no difference for males (*F* (1.81, 45.284) =

1.83, p =.17), a small significant difference was found for females (F (3.01,168.578) = 2.67, p =.049).

In addition, results indicate moderate evidence for no difference in concentrate quantity in relation to the events (BF (14) = .195 p <0.001) (Table 5.1). Analyses stratified by sex indicated no significant differences for males (F (5, 42.54) = 2.836, p =.40) or females (F (1.85, 20.397) = 2.49, p =.11). Changes in hash quantity also indicate moderate evidence for no effect over time (BF (14) = .066, p<0.001). No significant differences were found for males (F (1.26, 3.764) = 3.21, p =.154) or females (F (1.32, 10.52) = .951, p =.379).

An increasing trend in quantity of average vaping was found over time (BF (14, 130.955) = .954 p < 0.001), although the Bf <3 (Table 3). Analyses stratified by sex indicated a significant increase for females (F (2.558, 71.632) = 2.922, p =.048). Although there was no significant difference for males (F (1.57, 25.11) =1.296, p =.29), an average increase is seen before and after legalization and COVID-19, but a decrease from before and after EVALI.

Table 5.1 Changes in overall quantity of cannabis consumption forms for total sample population and separate analyses for males and females, before and after 3 events: Legalization of recreational cannabis in Canada, EVALI, and the COVID-19 pandemic.

	Legalization		EVALI		COVID-19		***p*-value**
	Before M (SD)	After M (SD)	Before M (SD)	After M (SD)	Before M (SD)	After M (SD)	
Herb (grams)							
Total n=177	1.1 (1.8)	1.3 (1.1)	1.3 (1.1)	1.3 (1.1)	1.4 (2.1)	1.5 (2.3)	<.001[‡]
Males n=76	1.6 (.23)	1.7 (2.3)	1.7 (2.3)	1.7 (2.3)	1.7 (2.3)	1.9 (2.6)	.41[†]
Females n=101	.67 (1.2)[a]	1.0 (1.7)[a]	1.0 (1.7)	1.1 (1.7)	1.1 (1.9)	1.2 (2.1)	.004[†]
Joint Size (grams)							
Total n=83	.61 (.43)	.74 (.36)	.68 (.39)	.73 (.36)	.69 (.38)	.66 (.43)	<.001[‡]
Males n=26	.72 (.41)	.81 (.34)	.75 (.35)	.82 (.31)	.76 (.32)	.76 (.39)	.17[†]
Females n=57	.56 (.43)	.71 (.37)	.64 (.40)	.68 (.37)	.66 (.40)	.62 (.44)	.049[†]
Number of Joints							
Total n=84	.77 (.88)	.98 (.97)	.88 (.94)	.96 (.97)	.90 (.91)	1.1 (1.3)	<.001[‡]
Males n=27	1.2 (1.1)	1.5 (1.2)	1.3 (1.2)	1.6 (1.2)	1.3 (1.1)	1.4 (1.5)	.049[†]
Females n=57	.58 (.70)	.72 (.70)	.66 (.70)	.68 (.69)	.72 (.78)	.86 (1.1)	.006[†]
Hash (grams)							
Total n=13	.42 (.52)	.52 (.54)	.40 (.26)	.33 (.19)	.25 (.23)	.33 (.30)	<.001[‡]
Males n=4	.38 (.25)	.69 (.38)	.44 (.13)	.44 (.13)	.44 (.13)	.44 (.13)	.15[†]
Females n=9	.44 (.62)	44 (.61)	.39 (.31)	.28 (.195)	.17 (.22)	.28 (.341)	.39[†]
Concentrates (grams)							
Total n=28	.32 (.45)	.41 (.31)	.44 (.43)	.43 (.31)	.46 (.42)	.57 (.51)	<.001[‡]
Males n=16	.39 (.54)	.47 (.35)	.53 (.51)	.50 (.33)	.56 (.49)	.63 (.51)	.40[†]
Females n=12	.23 (.29)	.33 (.25)	.31 (.26)	.33 (.27)	.33 (.27)	.50 (.53)	.11[†]

Number of vaping cartridges							
Total n=46	.35 (.80)	.71 (1.1)	.74 (1.2)	.82 (1.1)	.82 (1.3)	1.1 (1.5)	<.001[‡]
Males n=17	.50 (1.2)	.97 (1.3)	1.2 (1.5)	1.0 (1.3)	1.2 (1.9)	1.4 (2.0)	.29[†]
Females n=29	.26 (.46)	.55 (.99)	.47 (.82)	.69 (.97)	.62 (.66)	.87 (1.1)	.048[†]

Note: Bayesian Estimates of Group Means using repeated measures analysis of variance (ANOVA) indicates statistical significance within-subject differences for total sub-sample of each form used[‡]. General linear models using repeated measures ANOVA for within-subject differences for females and males using Greenhouse-Geisser correction[†]. Means in the rows denoted by the same subscript[a] are significantly different from one another (p <.05) as indicated by a Bonferroni post hoc test. n may not add up to due missing data.

5.6 Discussion

This study contributes to the complex and evolving landscape of cannabis consumption by examining changes associated with various quantity measures of cannabis forms consumed through smoking and vaping before and after political amendments (legalization), public health concerns (EVALI) and unprecedented natural societal health threats (COVID-19). The findings from this study provide insight into salient predictors of cannabis use among EA. The current legislation of recreational cannabis consumption puts EA in a social environment that allows for easy accessibility and experimentation, and vulnerable to health-risks. Recent evidence has shown an increase in the prevalence of cannabis users since legalization (Rotermann, 2020). The current study contributes to this evidence, suggesting that other measures of consumption, specifically the average quantity used by an individual may also increase. This was observed among females in particular.

For a clearer estimation of quantity, the quantity measures of the various cannabis forms in this study can be compared to a recent Canadian study that established an algorithm for measuring quantity of various cannabis forms in standard joint-size equivalents (Callaghan et al., 2020). Callaghan et al. (2020) developed standard measurements of multiple cannabis forms equivalent to a joint that contains 0.5 g of dried cannabis – the smallest retail joint size sold in provincial/territorial government cannabis stores. To illustrate, physical production equivalencies across major cannabis-products compared to a joint containing 0.5 g of dried cannabis is equivalent to: 0.125 g of hash, 0.096 g of cannabis oil for oil cartridges, and 0.096 g of concentrate (Callaghan et al., 2020). Comparatively, our study shows that on average users are consuming more than 1 joint equivalent amounts of cannabis per day of dried herb, hash, and concentrate, and within a month of using vaping cartridges. In addition, our study shows that the average joint size is larger than the standard joint size indicated by Callaghan et al. (2020), thus

the quantity of cannabis consumed may be underestimated for the EA population. These findings may aid in the prediction of cannabis-related harms and low-risk guidelines of various exposure profiles in relation to smoking and vaping intoxication for policy domains (Callaghan et al., 2020; Fischer et al., 2017).

Our findings also indicate notable differences in quantity of consumption for the various cannabis forms analyzed in this study stratified by sex. While males show consistent patterns of use in relation to herb quantity, the average quantity of herb used by males is higher than the average quantity used by females at all time points. In addition, higher quantities of cannabis were evident for all forms of cannabis measured in this study for males compared to females. Our findings also support evidence which indicates, males use higher potency cannabis products, particularly concentrates, which has been linked to a greater risk of dependence (Greaves & Hemsing, 2020).

Overall the primary findings of this study suggest that cannabis quantity may change over time, and in relation to specific events. This is indicated by an overall average increase in quantity for cannabis forms including, dried herb, concentrates, number of joints, and vaping cartridges, from before legalization of cannabis in Canada (October, 2018), to after the declaration of the COVID-19 pandemic (March, 2020). Specifically, an increasing trend was found over time in relation to the quantity of dried herb, which was the most common form used in this study. It is also interesting to note that in some cases, the quantity of use is lower at the start of each new event relative to the end of the previous one. Although joint size and the number of joints smoked on a typical day increased after legalization, an average decrease was observed from the time frame following legalization and before EVALI was declared an epidemic. However, while joint size decreased, the number of joints per day increased from

before to after the declaration of the pandemic for females. These inconsistent patterns which show an average increase in relation to specific events followed by a decline suggest that cannabis consumption behaviors may be associated with changing social and cultural contexts, events and life trajectory (negative events) among recreational users.

For example, although cannabis quantity may increase initially, as users develop an interest for the effects and in engage in the liberty of cannabis laws that allow accessibility to diverse strains and forms that may appeal to recreational cannabis users, this may not result in sustained increase in consumption quantity. Other socially and externally inducing contexts may negatively influence consumption based on factors such as perception of risk associated with consumption (i.e., respiratory illnesses). Alternatively, psychosocial associated risk factors brought forth due to the COVID-19 pandemic, such as lockdowns, isolation, inducing acute and chronic stressors may have positively influenced consumption (Cherkasova, 2020).

Although THC containing vaping products have been found to play a key role in the propagation of the EVALI epidemic (Patel et al., 2020; Chand et al., 2020), our study suggests an increasing trend in THC-based vaping product usage among EA. Thus, the EVALI outbreak may not have negatively influenced vaping consumption. This is line with recent evidence from the USA showing that information regarding the role of THC-based vaping oils, and vitamin E acetate are not significantly changing risk perceptions surrounding vaping products in current users (Patel et al., 2020). However, compared to the USA, EVALI cases remain substantially low in Canada, which may explain our study findings of increased average vaping quantity.

Moreover, cannabis vaping may lead to an increase in quantity over time, as vaping becomes a consistent and repetitive behavior, and leads to more puffs being taken during each session, thus limiting the time that one vaping cartridge might last. Consequentially, vaping high

potency cannabis extracts – commonly reported among EA (Meier, 2017) – may magnify the risk of developing CUD, due to a higher likelihood of building tolerance over time and experiencing withdrawal symptoms (Budney & Borodovsky, 2017; Loflin & Earleywine, 2014). In addition, the increased usage of vaping products may have important clinical implications, as research remains in its infancy regarding the health effects in relation to its compared advantages and disadvantages to methods of combustion (Loflin & Earleywine, 2015).

Recent studies have focused on the quantity of joints used in a day following the COVID-19 pandemic (Van Laar et al., 2020; Vanderbruggen et al., 2020). Specifically, in line with findings from a study in the Netherlands (Van Laar et al., 2020), we found an increase in the average number of joints after the declaration of the pandemic. Although, in Belgium, Vanderbruggen et al. (2020) did not find any changes in the number of joint days smoked per day, although individuals reported increases in smoking tobacco and alcohol. Increases in quantity of cannabis smoked may be particular to age-specific groups, as the mean age of individuals was 42.1 (14.6) years in the Belgium study, whereas the other study examined changes in a younger cohort (mean years: 32.7) (Van Laar et al., 2020).

Stress induced motivations for vaping is highly common among young Canadians, with at least 24% of EA (20 to 24) reporting it as their primary motivation (Statistics Canada, 2020). Thus, the average increase in vaping before to after COVID-19 may reflect stress-related motivations for use. Indeed, evidence suggests the link between situational factors and cannabis use, particularly for managing negative emotions or enhancing positive emotions (Walsh et al., 2017; Hyman & Sinha, 2009). Generally, using cannabis is a popularly sought substance among EA to alleviate boredom and to self-treat psychiatric symptoms, such as post-traumatic stress disorder (PTSD), anxiety, and insomnia (Lee et al., 2007; Maslowsky & Ozer, 2014).

Furthermore, consumption may also be influenced by sex-specific motives for use, and represent higher risk for dependence. For example, females are likely to demonstrate stronger coping motive links to use cannabis (Joyce et al., 2021). In light of the various psychological impacts that COVID-19 has had, increased quantity demonstrated by females in particular may be related to maladaptive coping strategies, such as distraction seeking and emotion-oriented coping (Esterwood & Saeed, 2020).

It is important to note that although research indicates an increase in prevalence of females using cannabis, more research is required to delineate the effects of specific forms of cannabis used in relation to sex-specific mechanisms (Greaves & Hemsing, 2020). For example, quantity of consumption may vary in relation to sex based on the amount of cannabis needed to achieve desired effects. Quantity of consumption is an important indicator of psychoactive effects, which is dependent upon the dose used (Walden & Earleywine, 2008; Matheson et al., 2020). Quantity measures in this study may be different for females compared to males since physiologically, females need to smoke a lower quantity and thus need a lower dose of THC inhaled to achieve the same acute effects as males (Matheson et al., 2020). These findings highlight the importance of clinical implications in examining biological mechanisms contributing to sex differences in the acute effects of THC, and in relation to varying cannabis exposures (e.g., quantity, frequency, methods, forms).

Limitations and future directions

This study sheds light on cannabis use trends in relation to single-item indicators by examining specific measures in relation to quantity of various cannabis forms, where limited research exists. These findings reveal unique aspects of the amount consumed of various cannabis forms in relation to sex, and may aid in determining adverse or harm-reduction

measures of consumption. Continued efforts to examine quantity can have important implications for prevention and treatment of cannabis-related problems. In addition, to our knowledge this is the first study to examine how quantity measures of multiple cannabis forms may change in relation to legalization, EVALI, and COVID-19 by sex-specific analyses. Despite these strengths, there are limitations to consider. First, asking participants to retrospectively report cannabis consumption behaviors in relation to specific measurements of quantity may have introduced recall bias. Due to the cross-sectional exploratory design of this study we cannot make any causal inferences. Therefore, it is unclear if the events had a direct affect on quantity of consumption. In addition, infrequent or varying use, and sharing - which is common among cannabis users - can limit reporting capacity (Rotermann, 2019).

It is important to note that, our study asked participants to report their quantity personally used, which may indicate that users are personally increasing their quantity of use, as a result of the social restrictions of the pandemic. We only assessed the mean use of cannabis per day for dried herb, concentrates, and hash, which may have led to under-reporting of use, and limit the cumulative quantity of consumption. In addition, participants were able to choose more than one form to report as their primary form of use. Therefore, changes in quantity may be due to switching from one form to another, or using non-combustion or vaping methods (i.e., orally administered forms) during the course of time examined in this study. Indeed, cannabis users tend to use more than one form regularly (Rotermann, 2019), which makes it difficult to accurately examine patterns of quantity consumption for one specific form or method of consumption.

In addition, more people reported using herb in its dried form and in the form of joints than any other form. This may have limited the power to examine significant changes in quantity

for other forms in this study, including, hash and concentrates. Moreover, examining vaping quantity is difficult as there are a diverse range of vaping devices, forms of cannabis used in vaping devices, as well as the size of cartridges and tanks used (Wong et al., 2019).

5.6 Conclusion

Given the substantial changes (all within a relatively short time span) in relation to cannabis policy, corresponding health risks associated with cannabis products and its derivatives, and emerging respiratory illnesses (EVALI and COVID-19) that make cannabis users that smoke or vape particularly vulnerable, examining changes in consumption can provide timely evidence of health-risk behaviors. Greater access to cannabis may increase the quantity of use over time and subsequently built tolerance. Therefore, quantity of consumption may be critical in addressing the progression of cannabis use disorder, as well as the relationship between measures of consumption and physiological health risks. Alleviating mental health complications and attenuating boredom during a pandemic may outweigh the perceived risks of respiratory issues among EA to reduce cannabis consumption, especially among heavy consumers. Cannabis vaping and smoking and associated behaviors, such as sharing and unintended aftermath consequences of substance increase following the reduction of restrictive measures, impose concerning health risks. Further research is needed to examine the predictors of changes in cannabis consumption behaviors and how these patterns may be influenced by the complex interactions of biological and psychosocial factors.

References for Chapter 5

Asbridge, M., Duff, C., Marsh, D. C., and Erickson, P. G. (2014). Problems with the identification of 'problematic'cannabis use: Examining the issues of frequency, quantity, and drug use environment. *European addiction research*, *20*(5), 254-267.doi: 10.1159/000360697

Beard, E., Dienes, Z., Muirhead, C., and West, R. (2016). Using Bayes factors for testing hypotheses about intervention effectiveness in addictions research. *Addiction (Abingdon, England)*, *111*(12), 2230–2247. doi:10.1111/add.13501

Borgonhi, E. M., Volpatto, V. L., Ornell, F., Rabelo-da-Ponte, F. D., and Kessler, F. H. P. (2021). Multiple clinical risks for cannabis users during the COVID-19 pandemic. *Addiction Science and Clinical Practice*, *16*(1), 1-4. https://doi.org/10.1186/s13722-021-00214-0

Braymiller, J. L., Barrington-Trimis, J. L., Leventhal, A. M., Islam, T., Kechter, A., Krueger, E. A., ... and McConnell, R. (2020). Assessment of Nicotine and Cannabis Vaping and Respiratory Symptoms in Young Adults. *JAMA network open*, *3*(12), e2030189-e2030189. doi:10.1001/jamanetworkopen.2020.30189

Budney, A. J., and Borodovsky, J. T. (2017). The potential impact of cannabis legalization on the development of cannabis use disorders. *Preventive medicine*, *104*, 31-36. doi: http://dx.doi.org/10.1016/j.ypmed.2017.06.034

Callaghan, R. C., Sanches, M., Benny, C., Stockwell, T., Sherk, A., and Kish, S. J. (2019). Who consumes most of the cannabis in Canada? Profiles of cannabis consumption by quantity. *Drug and alcohol dependence*, *205*, 107587. https://doi.org/10.1016/j.drugalcdep.2019.107587

Chand, H. S., Muthumalage, T., Maziak, W., and Rahman, I. (2020). Pulmonary toxicity and the pathophysiology of electronic cigarette, or vaping product, use associated lung injury. *Frontiers in pharmacology*, *10*, 1619. doi: 10.3389/fphar.2019.01619

Cherkasova M. (2020). Addiction in the times of pandemic. *The Canadian Journal of Addiction*, *11*(2), 9–12. https://doi.org/10.1097/CXA.0000000000000082

Cuttler, C., and Spradlin, A. (2017). Measuring cannabis consumption: Psychometric properties of the daily sessions, frequency, age of onset, and quantity of cannabis use inventory (DFAQ-CU). *PLoS One*, *12*(5), e0178194.

Dumas, T. M., Ellis, W., and Litt, D. M. (2020). What does adolescent substance use look like during the COVID-19 pandemic? Examining changes in frequency, social contexts, and pandemic-related predictors. *Journal of Adolescent Health*, *67*(3), 354-361. https://doi.org/10.1016/j.jadohealth.2020.06.018

Ellington, S., Salvatore, P. P., Ko, J., Danielson, M., Kim, L., Cyrus, A., ... and Wallace, B. M. (2020). Update: product, substance-use, and demographic characteristics of hospitalized patients in a nationwide outbreak of e-cigarette, or vaping, product use–associated lung injury—United States, August 2019–January 2020. *Morbidity and Mortality Weekly Report*, *69*(2), 44.

Esterwood, E., and Saeed, S. A. (2020). Past Epidemics, Natural Disasters, COVID19, and Mental Health: Learning from History as we Deal with the Present and Prepare for the Future. *The Psychiatric quarterly*, *91*(4), 1121–1133. https://doi.org/10.1007/s11126-020-09808-4

Fischer, B., Russell, C., Sabioni, P., Van Den Brink, W., Le Foll, B., Hall, W., ... and Room, R. (2017). Lower-risk cannabis use guidelines: a comprehensive update of evidence and recommendations. *American journal of public health*, *107*(8), e1-e12.

Gloss, D. (2015). An overview of products and bias in research. *Neurotherapeutics*, *12*(4), 731-734. doi:10.1007/s13311-015-0370-x

Greaves, L., and Hemsing, N. (2020). Sex and gender interactions on the use and impact of recreational cannabis. *International journal of environmental research and public health*, *17*(2), 509. doi:10.3390/ijerph17020509

Hammond D., Goodman S., Leos-Toro C., Wadsworth E., Reid JL., Hall W., Pacul R., Driezen P., George T., Rehm J., Werb D., Boudreau C., Porath A., Abramovic H., Elliot R (2018). International Cannabis Policy Survey.

Harris-Lane, L., Winters, E., and Harris, N. (2020). Emerging Adult Perceptions of Cannabis Use Based on Age and Sex of User. *Emerging Adulthood*, 2167696820930862. doi: 10.1177/2167696820930862

Hyman, S. M., and Sinha, R. (2009). Stress-related factors in cannabis use and misuse: implications for prevention and treatment. *Journal of substance abuse treatment*, *36*(4), 400-413. doi:10.1016/j.jsat.2008.08.005

Jeffreys, H. (1961). *Theory of Probability, 3rd Edn*. Oxford, UK: Oxford University Press.

Jones, C.B., Hill, M.L., Pardini, D.A., Meier, M.H. (2016). Prevalence and correlates of vaping cannabis in a sample of young adults. Psychol. Addict. Behav. 30, 915–921. https://doi.org/10.1037/adb0000217

Joyce, K. M., Thompson, K., Good, K. P., Tibbo, P. G., O'Leary, M. E., Perrot, T. S., ... and Stewart, S. H. (2021). The impact of depressed mood and coping motives on cannabis use quantity across the menstrual cycle in those with and without pre-menstrual dysphoric disorder. *Addiction*. doi:10.1111/add.15465

King, B. A., Jones, C. M., Baldwin, G. T., and Briss, P. A. (2020). The EVALI and youth vaping epidemics—implications for public health. *New England Journal of Medicine*, *382*(8), 689-691. doi: 10.1056/NEJMp1916171

Kreslake, J. M., Diaz, M. C., Shinaba, M., Vallone, D. M., and Hair, E. C. (2021). Youth and young adult risk perceptions and behaviours in response to an outbreak of e-cigarette/vaping-associated lung injury (EVALI) in the USA. *Tobacco Control*. http://dx.doi.org/10.1136/tobaccocontrol-2020-056090

Lee, D. C., Crosier, B. S., Borodovsky, J. T., Sargent, J. D., and Budney, A. J. (2016). Online survey characterizing vaporizer use among cannabis users. *Drug and alcohol dependence*, *159*, 227-233. doi: 10.1016/j.drugalcdep.2015.12.020

Lee, C. M., Neighbors, C., and Woods, B. A. (2007). Marijuana motives: young adults' reasons for using marijuana. *Addictive behaviors*, *32*(7), 1384–1394. doi: 10.17269/CJPH.108.5955

Lee, M. D., and Wagenmakers, E. J. (2014). *Bayesian Cognitive Modeling: A Practical Course*. Cambridge: Cambridge University Press.

Leos-Toro, C., Rynard, V., and Hammond, D. (2018). Prevalence of problematic cannabis use in Canada: Cross-sectional findings from the 2013 Canadian Tobacco, Alcohol and Drugs Survey. *Canadian journal of public health = Revue canadienne de sante publique*, *108*(5-6), e516–e522. https://doi.org/10.17269/cjph.108.5955

Leos-Toro, C., Fong, G. T., Meyer, S. B., and Hammond, D. (2020). Cannabis health knowledge and risk perceptions among Canadian youth and young adults. *Harm reduction journal*, *17*(1), 1-13. https://doi.org/10.1186/s12954-020-00397-w

Looby, A., and Earleywine, M. (2007). Negative consequences associated with dependence in daily cannabis users. *Substance abuse treatment, prevention, and policy*, *2*(1), 1-7. https://doi.org/10.1186/1747-597X-2-3

Loflin, M., and Earleywine, M. (2014). A new method of cannabis ingestion: the dangers of dabs?. *Addictive behaviors*, *39*(10), 1430-1433. doi: 10.1016/j.addbeh.2014.05.013

Loflin, M., and Earleywine, M. (2015). No smoke, no fire: what the initial literature suggests regarding vapourized cannabis and respiratory risk. *Canadian journal of respiratory therapy: CJRT= Revue canadienne de la therapie respiratoire: RCTR*, *51*(1), 7.

Maslowsky, J., and Ozer, E. J. (2014). Developmental trends in sleep duration in adolescence and young adulthood: evidence from a national United States sample. *Journal of Adolescent Health*, *54*(6), 691-697.

Matheson, J., Sproule, B., Di Ciano, P., Fares, A., Le Foll, B., Mann, R. E., and Brands, B. (2020). Sex differences in the acute effects of smoked cannabis: evidence from a human laboratory study of young adults. *Psychopharmacology*, *237*(2), 305-316. doi: http://dx.doi.org/10.1007/s00213-019-05369-y

Meier, M. H. (2017). Associations between butane hash oil use and cannabis-related problems. *Drug and alcohol dependence*, *179*, 25-31. http://dx.doi.org/10.1016/j.drugalcdep.2017.06.015

Mostaghim, A., and Hathaway, A. D. (2013). Identity formation, marijuana and "the self": A study of cannabis normalization among university students. *Frontiers in psychiatry*, *4*, 160. doi: 10.3389/fpsyt.2013.00160

Patel, T., Karle, E., Gubeladze, T., Pentecost, G., and Krvavac, A. (2020). Patient Perception of Vaping in the Midst of the Electronic Cigarette and Vaping Product Associated Lung Injury (EVALI) Epidemic. *Missouri medicine*, *117*(3), 265–270.

Rotermann, M. (2020). What has changed since cannabis was legalized. *Health Rep*, *31*(2), 11-20.

Rotermann, M. (2019). Analysis of trends in the prevalence of cannabis use and related metrics in Canada. *Health reports*, *30*(6), 3-13.

Rotermann, M., and Macdonald, R. (2018). Analysis of trends in the prevalence of cannabis use in Canada, 1985 to 2015. *Health reports*, *29*(2), 10-20.

Russell, C., Rueda, S., Room, R., Tyndall, M., and Fischer, B. (2018). Routes of administration for cannabis use–basic prevalence and related health outcomes: A scoping review and synthesis. *International Journal of Drug Policy*, *52*, 87-96. https://doi.org/10.1016/j.drugpo.2017.11.008

Statistics Canada. (2020). *Canadian Tobacco and Nicotine Survey*. Retrieved from https://www150.statcan.gc.ca/n1/en/daily-quotidien/210317/dq210317b-eng.pdf?st=YdcSXcx1

Vanderbruggen, N., Matthys, F., Van Laere, S., Zeeuws, D., Santermans, L., Van den Ameele, S., and Crunelle, C. L. (2020). Self-reported alcohol, tobacco, and Cannabis use during COVID-19 lockdown measures: results from a web-based survey. *European Addiction Research*, *26*(6), 309-315. doi: 10.1159/000510822

Van Der Pol, P., Liebregts, N., De Graaf, R., Korf, D. J., van den Brink, W., and van Laar, M. (2013). Predicting the transition from frequent cannabis use to cannabis dependence: a three-year prospective study. *Drug and Alcohol Dependence*, *133*(2), 352-359. https://doi.org/10.1016/j.drugalcdep.2013.06.009

Van Laar, M. W., Oomen, P. E., Van Miltenburg, C. J., Vercoulen, E., Freeman, T. P., and Hall, W. D. (2020). Cannabis and COVID-19: Reasons for Concern. *Frontiers in psychiatry*, *11*, 1419. doi: 10.3389/fpsyt.2020.601653

Government of Canada (2020). *Vaping-associated lung illness*. Available via. https://www.canada.ca/en/public-health/services/diseases/vaping-pulmonary-illness.html, Accessed date: 19 April 2021.

Walden, N., and Earleywine, M. (2008). How high: quantity as a predictor of cannabis-related problems. *Harm reduction journal*, *5*, 20. https://doi.org/10.1186/1477-7517-5-20

Walsh, Z., Gonzalez, R., Crosby, K., Thiessen, M. S., Carroll, C., and Bonn-Miller, M. O. (2017). Medical cannabis and mental health: A guided systematic review. Clinical Psychology Review, 51, 15–29. doi: 10.1016/j.cpr.2016.10.002

Wong, S. W., Lin, H. C., Piper, M. E., Siddiqui, A., and Buu, A. (2019). Measuring characteristics of e-cigarette consumption among college students. *Journal of American college health : J of ACH*, *67*(4), 338–347. https://doi.org/10.1080/07448481.2018.1481075

Zeisser, C., Thompson, K., Stockwell, T., Duff, C., Chow, C., Vallance, K., ... and Lucas, P. (2012). A 'standard joint'? The role of quantity in predicting cannabis-related problems. *Addiction Research and Theory*, *20*(1), 82-92. Doi: 10.3109/16066359.2011

Chapter 6. Manuscript 3

Respiratory symptoms in relation to cannabis consumption behaviors of emerging adults

6.1 Abstract

Research on cannabis consumption has emphasized the clinical need of examining various measures (frequency and quantity), methods and forms of consumption as predictors of respiratory health risks in relation to sex. With diversification of cannabis consumption methods (e.g., vaping) and increased prevalence of dual cannabis use (smoking and vaping), examining respiratory outcomes is essential to inform public health risks. The objectives of this study were to i) characterize sex-specific differences in cannabis consumption profiles, and ii) to examine respiratory symptoms in relation to cannabis exposure profiles based on sex-specific differences. Cross-sectional survey data were obtained from 312 EA (18-29) in Canada after the declaration of the COVID-19 pandemic between May 2020 to August 2020, that smoked or vaped cannabis in the last 12 months. Binary logistic regression models were conducted to examine significant predictors in relation to cannabis exposure profiles and reporting at least one respiratory symptom for the overall sample and separately for sex (females vs. males). Dry cough was more prevalent for males ($p<0.05$). Frequency of vaping or dual use is a protective factor of respiratory symptoms among females. Our data suggest that, respiratory symptoms among male and female cannabis users that smoke and or vape are prevalent, which may increase the risk of susceptibility to adverse respiratory health consequences later in life. Future research should continue to examine multiple correlates and determinants of respiratory health outcomes in relation to cannabis consumption exposure profiles in relation to gender and sex-specific factors.

Keywords: cannabis; emerging adults; respiratory symptoms; sex; smoking; vaping

6.2 Introduction

As a previously illicit substance, cannabis is considered the most "normalized" substance to be legislatively implemented as a licit substance in Canada (Osborne & Fogel, 2016). The reform which occurred in October 2018 has brought alongside apprehensions regarding the long-term health sequalae and increased consumption among youth – often considered as vulnerable and the most prevalent consumers (Johnson & Guttmannova, 2019; Stone et al., 2012; Wadsworth & Hammond, 2018).

While consumption patterns are considered to peak during emerging adulthood, the age of cannabis initiation often occurs before the age of 14 (Leos-Toro et al., 2020; Stone et al., 2012), and with mean age of onset for dependence founded from ages 15 to 18 (Behrendt et al., 2009; Van Der Pol et al., 2013). Early initiation followed by consistent consumption may increase the impact of long-term health-risks. For example, research shows that early initiation and frequent cannabis smoking can translate to symptoms reflective of chronic obstructive pulmonary disease (COPD) during emerging adulthood (Taylor et al., 2000; Morris et al., 2018), suggesting that health-risks associated with cannabis use may become apparent during a critical period of development, and even after short-term use (Hancox et al., 2015). Since lung growth and volume are still undergoing maturation during 18 to 20 years of age in females, and 20 to 24 years of age in males (Coates et al., 2013), the risks of habitual smoking and early initiation may present greater harm.

Sex-specific differences in cannabis consumption behaviors may impact health risks (Greaves & Hemsing, 2020). For example, males are more likely to report more frequent and high quantities than females (Cuttler & Sexton, 2016). In relation to health outcomes, when accounting for sex as a biological variable, differences in anatomical lung characteristics, including smaller lung size, volume and conducting airways in females than males may mediate

the risk of adverse physiological respiratory effects from smoking or vaping cannabis (Groenveld, 2020). Indeed, substantial epidemiological evidence suggests that the incidence, susceptibility and severity of several lung diseases is influenced by sex (LoMauro & Aliverti, 2018). For example, females show greater vulnerability to tobacco smoking than males, with a higher risk of reporting respiratory symptoms (Barnes, 2016). The respiratory risks associated with smoking cannabis have been compared to symptoms experienced among tobacco smokers (Ghasemiesfe et al., 2018; Ribeiro & Ind, 2016); however, it remains unclear whether respiratory exposure to combustion of cannabis and aerosols emitted from vaping cannabis may influence sex differences in respiratory outcomes.

Furthermore, previous reviews of respiratory risk associated with cannabis consumption highlight that most research does not examine the type of inhalation mechanism (Gates et al., 2014; Ghasemiesfe, 2018; Loflin & Earleywine, 2015; Ribeiro & Ind, 2016). Different smoking methods may alter the characteristics of the combusted products, and thus the level of carcinogenic compounds inhaled (Russel et al., 2018). For example, vaping cannabis may reduce the carcinogenic compounds found in tobacco and cannabis smoke, thus suggesting a reduction in respiratory harms (Earleywine & Barnwell, 2007). A recent study found that compared to never vapers, the odds of wheezing increased more than 2-fold among youth who vaped cannabis 3 or more times in the past 30 days (Braymiller et al., 2020).

The variability in mode of inhalation used (eg, joints, pipes, bongs, vaporizers), coupled with a lack of research differentiating users based on inhalation method, makes estimating risk associated with inhaling cannabis difficult (Loflin & Earleywine, 2015). In addition, there have been very few recent studies on the impact of cannabis smoking and vaping on respiratory health, mostly due to previous legality issues, recent popularization of novel methods and the

confounding effects of tobacco (Ribeiro & Ind, 2016; Russel et al., 2018). The risks of additional by-products used in vaping devices and the material of devices constructed from plastic and metal may pose unknown respiratory health-risks (Budney et al., 2015). Vaping products (i.e., oils and flavors) require substantive manipulation and alteration with the addition of solvents such as propylene glycol (PG), vegetable glycerin (VG), and vitamin-e acetate for effective delivery of the substance in the form of vapor (Chand et al., 2020; Troutt & DiDonato, 2017). When heated, these products may produce carcinogenic compounds such as formaldehyde and oxidant derivatives that may affect physiological lung functions (Chand et al., 2020). These products have been speculated in the risk of 'e-cigarette and vaping associated lung illnesses' (EVALI) (Aberegg et al., 2020; Kazachkov & Pirzada, 2020).

This is particularly concerning in the era of respiratory illnesses and pandemics. Indeed, current cannabis use has been associated with more outpatient visits for respiratory illnesses (such as cold, flu, or sore throat) and respiratory problems (Ghasemiesfe et al., 2018). Since EA in Canada have the highest rates of trying novel inhalation methods and represent the most prevalent consumers (Rotermann, 2020), they may be more at risk for infection by respiratory viruses, such as the novel coronavirus (COVID-19) (Gaiha et al., 2020). Consequently, given the many developments in relation to changing cannabis policy landscapes, a worldwide pandemic, and the emerging new methods of consumption, research related to links between varying cannabis exposure profiles and health outcomes is relatively limited and in dire need of exploration (Ribeiro & Ind, 2018). Accordingly, this study aims to i) characterize sex-specific differences in cannabis consumption profiles, and ii) examine sex-specific differences in respiratory symptoms in relation to cannabis consumption exposure profiles.

6.3 Methods

Participant recruitment

In order to participate in this study, participants must have met the following inclusion criteria: reported smoking and/or vaping cannabis in the last 12 months, currently lived in Canada, and were 18 to 29 years old. Convenience sampling was used to recruit participants ages 18 to 29 from social media platforms. Social media pages and accounts were created on Facebook (@OntarioTechCCPStudy) and Twitter (@OTU_CCP_Study) pertaining to the study. Advertisements were created on each social media platform, and targeted to cannabis users by using terms and specifications suited for the age group (18 to 29 years old) and specifying country of residence (i.e., Canada), through proprietary marketing algorithms. Terms used to identify Facebook users' self-reported interests included, 'smoking'; 'vaping'; 'e-cigarettes'; 'cannabis'. Twitter ads and tweets involving the terms 'cannabis'; 'vaping'; 'weed'; 'smoking' was selected with corresponding hashtags, which targeted individuals with similar interests.

Participants were also recruited from Ontario Tech University through the communication server of the institution. An email was sent to all domestic students (residing in Canada). This included both incoming spring/summer (May to August 2020) students, and the past winter (January to April 2020) cohort. The survey link was also advertised on the Ontario Tech News website and in a local Durham Regions News article (Follert, 2020). The email and advertisements contained details regarding the study and procedures, as well as a link to the consent form and survey hosted on Google Forms. The survey was restricted to the English language, and consent was required to participate. No compensation was provided. All self-identifying information was removed and saved separately from the dataset, ensuring anonymity of participants.

Recruitment and data collection occurred from May 4, 2020, approximately 6 weeks after the declaration of the COVID-19 pandemic restrictions in Canada. Data collection continued to August 31, 2020. This study received ethics approval from the Ontario Tech University Research Ethics Board on May 4, 2020 [REB#15880].

Survey items

The survey was developed considering previous studies on cannabis consumption (Lee et al., 2016; Hancox et al., 2015; Taylor et al., 2000) and using various validated sources, including the *International Cannabis Policy Study* (Hammond et al., 2018), the *Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU* (Cuttler & Spradlin, 2017), and the *International Study of Asthma and Allergies in Childhood (ISAAC)* (Asher et al., 1995) questionnaire. The survey was piloted in late April 2020 with 11 participants between the ages of 18 to 29 who were current cannabis users. Piloting of the survey assessed the feasibility of completing the survey and clarity of the questions. No significant modifications to the survey were made.

From Ontario Tech University 109 individuals participated in the survey. From social media platforms 234 individuals participated in the survey. From both platforms, results of 343 individuals were reviewed, of which 312 were eligible. Respondents were excluded if they: accessed the survey but did not answer any questions regarding the inclusion and exclusion criteria (n=3), were not 18-29 years old (n=11), did not smoke or vape cannabis in the last 12 months (n=13) (e.g., only used edibles forms), or did not consent (n = 3).

Measures

Outcome

Respiratory symptoms. Four questions examined the prevalence of respiratory symptoms experienced. Items were extracted from the ISAAC questionnaire, and were

used because they proved sensitive to cannabis use in a previous study (Taylor et al., 2000) and also showed an impact of the vaporizer (Earleywine & Van Dam, 2010; Earleywine & Barnwell 2007): 'Have you had wheezing or whistling in the chest in the last 12 months?'; 'In the last 12 months, have you ever had a dry cough at night, apart from a cough associated with a cold or chest infection?'; 'In the last 12 months, have you coughed up phlegm in the morning?'; 'In the last 12 months, has your chest sounded wheezy during or after exercise?'. All response options were dichotomous (yes or no). Indicating 'yes' to at least one of four symptoms was used in analysis to examine correlates of respiratory symptoms in relation to cannabis exposure profiles stratified by sex.

Cannabis consumption measures

Cannabis consumption status. Cannabis users were grouped into the status of a vaper only, smoker only, or dual user based on whether they had ever vaped and/or smoked cannabis in the last 12 months.

Lifetime frequency of cannabis vaping or smoking. Participants reported the age that they initiated smoking or vaping and the cumulative lifetime days of smoking or vaping, using the following questions: 'How many days in your lifetime have you smoked cannabis?'; 'How many days in your lifetime have you vaped cannabis?' (Lee et al., 2016). A binary variable was created to differentiate an occasional user from an experienced user based on lifetime days of use. Occasional users included smoking or vaping: 1 to 2; 3 to 10; or 11 to 99 days in their life. Experienced users included those that reported 100 to 999 or more than 1000 days of lifetime smoking or vaping. Age of onset was assessed by the following two questions: "How old were

you when you started smoking cannabis?"; 'How old were you when you started vaping cannabis?".

Methods of consumption. To examine the methods used to smoke or vape cannabis, participants were asked: 'What is the 'primary' method you use to vape cannabis'; 'What is the 'primary' method you use to smoke cannabis? [Please note that by 'primary', we are referring to the method that you use predominantly, or most often?]' (DFAQ-CU);

Frequency and quantity. The most recent frequency and quantity measures of cannabis consumption reported for the time period after the COVID-19 pandemic declaration (March, 2020) was used to examine most recent patterns of use in relation to respiratory symptoms reported. Frequency response options were coded: 0=I did not smoke (or vape), 1= less than once a month, 2=once a month, 3=2-3 times a month, 4=once a week, 5=twice a week, 6=3-4 times a week, 7=5-6 times a week, 8=once a day, and 9=more than once a day (Cuttler & Spradlin, 2017). The frequency of vaping and smoking (after COVID-19) variable options were collapsed into binary categories: Less than daily (combining 0-7); Daily (combining 8 and 9). Quantity of cannabis in relation to the specific form of cannabis was assessed for, (1) dried herb (grams), (2) joint size (grams) (3) number of joints, (4) hash (grams), (5) concentrates (grams), and the (6) number of vaping cartridges used. If participants indicated a certain form of cannabis as the primary form they use (i.e., form used predominantly or most often), they were directed to the specific form used and the quantity measures: "On the days you use(d) dried herb, about how much did you personally use?"; "On the days you use(d) joints, what joint size is closest to the size you normally smoke(d)?"; "On the days you use(d) joint(s), how many did you smoke?"; "On the days you use(d) Hash/Hashish how much did you personally use?"; "On the days you use(d) concentrates how much did you personally use?". For vaping liquid/oil, participants were

asked: “How many vape cartridge(s) or refill(s) did you use in a month?”. Quantity measures were adopted from the International Cannabis Policy Study (Hammond et al., 2018).

Tobacco use. Smoking tobacco may similarly affect respiratory health symptoms of cannabis smokers, and many cannabis smokers may engage in co-use (Ghasemiesfe et al., 2018; Ribeiro & Ind, 2016). Therefore, two measures of tobacco smoking were included as covariates in the analysis predicting respiratory symptoms. In one item, participants indicated if they had ever smoked tobacco in the past 30 days. In a second item, participants reported if they had smoked tobacco 100 or more times in their life.

6.4 Data analysis

Data were analyzed using SPSS v 27 (IBM SPSS Statistics 27 ©). Descriptive statistics were conducted for outcomes and explanatory variables. Three sets of analyses were performed. First, Chi-square (χ^2) analyses evaluated differences in the frequency of respiratory symptoms reported by participants and differences in cannabis consumption exposure profiles in relation to sex (female vs. male). Second, χ^2 test (categorical variables) or t-test (continuous variable) were used to compare participants who did and did not report at least one respiratory symptom, in relation to cannabis exposure profiles. Third, all explanatory variables that were significant in the bi-variate analyses ($p < 0.20$) in relation to sex-specific differences and exposure profiles of cannabis consumption, were included in the binary logistic regression model using the enter method, to identify significant predictors of reporting at least one respiratory symptom. As per previous research, we used a p-value of <0.2 to screen for the most important independent indicators of reporting at least one respiratory symptom in the bi-variate analysis, for inclusion in the multivariable models (Machicado et al., 2017). These analyses were examined for the overall sample and stratified by sex to evaluate effects in males and females separately.

6.5 Results

Tables 6.1 and 6.2 highlight differences in cannabis consumption exposure profiles of male and female EA, and correlates of reporting at least one respiratory symptom, respectively. Among 312 participants, 39% were male. The mean age of the study sample was 23 years. The mean age of onset and majority of participants started smoking cannabis at 17 years, while the average age of vaping onset was much higher (21 years) for both males and females. Only 2% of users had exclusively vaped cannabis in the last 12 months. The majority of female cannabis users reported exclusively smoking in the last 12 months (68%), compared to 37% of males. The majority of the sample comprised of highly experienced (exclusive) cannabis smokers, with 63% of males and 54% of females reporting 100 or more lifetime days of smoking. Vaping only or dual use was less frequent, with 39% of males and 15% of females reporting 100 more lifetime days of consumption ($p<0.001$). The most popular type of smoking method indicated as the primary method used was a joint for males (37%) and females (34%), followed by a bong (31% vs. 28% for males and females, respectively).

There was a significant association between sex and hand pipe use, such that females were more likely to report using a hand pipe than males (χ^2 (1) = 8.21, p <0.01). The most popular type of vaping device endorsed was a vape pen, by both males and females (50% vs. 48%, respectively). There was a significant difference between males (15%) and females (7%) reporting concentrates as the primary form consumed (χ^2 (1) = 5.02, $p<0.05$) (Table 6.1).

A mean of 1.29 respiratory symptoms was reported (*SD* = 1.36), with responses ranging from 0 to all four symptoms. Wheezing/whistling in the chest within 12 months was reported by 26% of participants, while 28% indicated experiencing wheezing in the chest during or after exercise. Dry cough at night apart from a chest infection was reported by 30% of cannabis users. Almost half (44.9%) of the sample population reported phlegm in the last 12 months. A

significant association for sex and dry cough was found for males (χ^2 (1) = 4.83, $p < 0.05$). For reporting at least one respiratory symptom, significant differences were found for cannabis exposure profiles for males, females and for the overall sample (Table 6.2). Overall, associations were found in relation to lifetime frequency of vaping, frequency of smoking after the COVID-19 pandemic, smoking tobacco, primary vaping method used, primary forms including hash or concentrates, and quantity of dried herb consumed since the declaration of the COVID-19 pandemic (Table 6.2). Multivariable regression models suggest that there was a significant association between frequency of vaping/dual use with lower odds of reporting at least one respiratory symptom among females (OR .033; 95% CI, .001 - .885) (Table 6.3). Odds ratio for associations related to concentrate quantity and use of hash as the primary form used could not be obtained due to small sample size in these variables. There were no statistically significant associations between cannabis exposure profiles and respiratory symptoms for males and the overall sample.

Table 6.1. Cannabis consumption exposure profiles and prevalence of respiratory symptoms of total sample and differences between male and female cannabis users.

Variable	**Classification**	**n (%)**			***p*-value**[a]
		Overall	**Male** 123 (39.4)	**Female** 189 (60.6)	
Age of smoking onset M (SD)		17.33 (2.36)	17.22 (2.42)	17.39 (2.33)	.526
Age of vaping onset M (SD)		20.59 (3.08)	20.54 (3.32)	20.64 (2.97)	.839
Cannabis user status					.065
	Vaper only	5 (1.6)	2 (1.6)	3 (1.6)	
	Smoker only	142 (45.5)	46 (37.4)	96 (67.6)	
	Dual user	165 (52.9)	75 (61.0)	90 (47.6)	
Frequency of smoking (days)					.317
	Occasional (<100)	61 (19.6)	17 (37.0)	44 (45.8)	
	Frequent (≥ 100)	81 (26.0)	29 (63.0)	52 (54.2)	
Frequency of vaping/dual use (days)					**.000*** **
	Occasional (<100)	126 (74.1)	**47 (61.0)**	**79 (84.9)**	
	Frequent (≥ 100)	44 (25.9)	**30 (39.0)**	**14 (15.1)**	
Past 30-day smoking tobacco					.774
	Yes	63 (31.0)	27 (32.1)	36 (30.3)	
	No	140 (69.0)	57 (67.9)	83 (69.7)	
Smoked tobacco 100 or more times					.111
	Yes	81 (39.9)	39 (46.4)	42 (35.3)	
	No	122 (60.1)	45 (54.6)	77 (64.7)	
Frequency (since COVID-19)	**Smoking**				.145
	Less than once a month	66 (21.6)	20 (16.5)	46 (24.9)	
	Monthly	59 (19.3)	20 (16.5)	39 (21.1)	
	Weekly	75 (24.5)	35 (28.9)	40 (21.6)	
	Daily	106 (34.6)	46 (38.0)	60 (32.4)	
	Vaping				
	Less than once a month	86 (50.6)	35 (45.5)	51 (54.8)	.128
	Monthly	31 (18.2)	11 (14.3)	20 (21.5)	
	Weekly	32 (18.8)	19 (24.7)	13 (14.0)	
	Daily	21 (12.4)	12 (15.6)	9 (9.7)	
Primary forms					
	Dried herb	282 (90.4)	111 (90.2)	171 (90.5)	.946
	Hash/hashish	14 (4.5)	4 (3.3)	10 (5.3)	.395
	Concentrates	33 (10.6)	**19 (15.4)**	**14 (7.4)**	**.024***
	Vaping oil	47 (15.1)	18 (14.6)	29 (15.3)	.864
Primary smoking methods					
	Joint	109 (35.5)	45 (36.6)	64 (34.4)	.622
	Spliff	30 (9.8)	14 (11.4)	16 (8.5)	.393
	Blunt	8 (2.6)	5 (4.1)	3 (1.6)	.271[†]
	Hand pipe	48 (15.6)	**10 (8.3)**	**38 (20.1)**	**.004** **

	Bong	89 (29.0)	37 (30.6)	52 (28.0)	.623
	Other *(missing)*	23 (7.5)	10 (8.3)	13 (7.0)	
Primary vaping methods					
	Electronic Cigarette	3 (1.0)	0 (0.0)	3 (1.6)	.281[†]
	Vape Pen	81 (26.0)	37 (30.1)	44 (23.3)	.181
	Tabletop Vaporizer	2 (0.6)	1 (0.5)	1 (0.8)	1.0[†]
	Dab Pen	25 (8.0)	11 (8.9)	14 (7.4)	.625
	Dab Rig	8 (2.6)	4 (3.3)	4 (2.1)	.717[†]
	Portable Vaporizer	46 (14.7)	21 (17.1)	25 (13.2)	.349
Respiratory conditions					
	At least one symptom	189 (60.6)	76 (61.8)	113 (59.8)	.724
	Phlegm	140 (44.9)	85 (45.0)	55 (44.7)	.964
	Wheeze/whistling in chest	82 (26.3)	35 (28.5)	47 (24.9)	.482
	Chest wheeze during/after exercise	86 (27.7)	34 (27.9)	52 (27.5)	.945
	Dry cough	94 (30.1)	**46 (37.4)**	**48 (25.7)**	**.028***

Note: Categorical data are presented as frequency (percentage). Continuous data are presented as mean SD. [a]*P*-values were calculated with Chi-square (categorical data) and unpaired t-tests (Continuous data). Bold values indicate statistical significance $*p < 0.05$; $** \ p < 0.01$; $*** \ p < 0.001$. [†]Interpret results with caution given small cell counts. Fisher's exact test used to account for small cell sizes.

6.6 Discussion

Changes in the diversity, accessibility and popularity of cannabis consumption methods used to inhale vaporized and combusted forms of various cannabis products have occurred over a relatively short period of time. This necessitates the emphasis for research to examine the implications and effects on respiratory health of inhaled cannabis. Legalization regimes have simultaneously increased the opportunity to use diverse cannabis methods, modes and forms. Thus, it is important to examine the role of widely used and newly regulated cannabis products on health risks to inform and educate harm-reduction approaches, where previous research has been limited (Russel et al., 2018). Increasing consumption trends coinciding with a narrowing gender-gap in consumption practices further supports the need to apply a sex and gender-specific lens to examining patterns of consumption for more evidence-based informed public health responses (Hemsing & Greaves, 2018).

Our results suggest that there are small but significant sex-specific differences in preference for cannabis consumption methods. In line with findings from Cuttler & Mischley (2016), our findings show that females are more likely to primarily use pipes to smoke cannabis than males, although smoking joints and using bongs remain the most common primary methods of smoking among both sexes (Greaves & Hemsing, 2020). In addition, consistent with a study conducted in the USA we found that males are more likely to use concentrates than females (Daniulaityte et al., 2018). Since females have a higher sensitivity to higher concentrations of THC (Matheson et al., 2020), it may take more time for more females to experiment with this form of cannabis. Moreover, using concentrates was also significantly associated with living in states that have legalized recreational use (Daniulaityte et al., 2018). These findings may predict increasing trends of smoking and vaping cannabis concentrates in Canada.

In addition, findings also support evidence of an association between reporting at least one respiratory symptom and cannabis consumption exposure profiles. There was a significant difference in reporting dry cough in relation to sex, such that males reported a higher prevalence. These findings may correlate to a higher frequency and quantity of smoking and vaping among males than females in this study. Specifically, our findings are consistent with previous studies (Cuttler & Mischley, 2016; Lee et al., 2016; Rotermann, 2020), showing that males have more experience based on frequency of lifetime days of smoking and vaping consumption compared to females, and report a higher prevalence of dual use. Interestingly, our findings show that among females that vaped only or reported dual use (smoking and vaping), frequency of lifetime days of vaping/dual use (≥ 100 days of use) was protective of reporting at least one respiratory symptom. This indicates that further replication of such findings is needed to elucidate the effects of vaping only and dual use frequency of cannabis consumption in relation to sex-specific differences.

Exploratory studies have found that users' self-reported respiratory symptoms improved after switching from smoking cannabis to exclusively vaping after a month (Earleywine & Van Dam, 2010; Van Dam & Earleywine, 2010). However, a study by Earleywine & Barnwell (2007), suggests that these symptoms may covary with cumulative exposure in relation to quantity used. In addition, recent evidence indicates that in comparison to individuals that have never vaped, vaping cannabis products including THC or hash oil, concentrated cannabis/dabs represented a risk factor for increased odds of reporting chronic bronchitis symptoms, after controlling for various variables, including cigarette and cannabis smoking, vaping nicotine and sociodemographic characteristics (Braymiller et al., 2020). This suggests that vaping forms of cannabis that are highly concentrated compared to dried herbs, including Butane Hash Oil (BHO), commonly referred to as "dabs" (Chan et al., 2017) which are typically manipulated with

thinning agents and other chemical constituents in vaping devices, may represent unique risks for respiratory health outcomes (Troutt & Didonato, 2017).

Although, nascent evidence suggests that the prevalence of dual use is increasing (smoking and vaping) (Jones et al., 2016; Lee et al., 2016), to our knowledge there is no research comparing the respiratory health risks associated with cannabis users that exclusively smoke cannabis, exclusively vape cannabis, or that engage in both methods (dual users). In line with previous research (Lee et al., 2016; Earleywine & Barnwell, 2007), only a small sample of users indicated exclusively vaping in our study. This suggests that users are likely to be initially smoking before adding vaping to their consumption, rather than engaging in vaping cannabis with no prior smoking exposure. Although, as users may transition to exclusively vaping, longitudinal analysis of cannabis consumer groups (i.e., exclusive smokers, exclusive vapers, and dual users) are needed to develop more clinical-based evidence of vaping as a harm reduction alternative.

Overall, our study shows that respiratory symptoms are risk factors of cannabis consumption during the period of emerging adulthood among those who smoke and/or vape cannabis. Consistent with the large body of research on respiratory risks (Ghasemeisfe et al., 2018; Martinasek et al., 2016), we found that respiratory symptoms including, phlegm, wheezing or whistling in the chest in the last 12 months, or wheezing and whistling in the chest during exercise, and dry cough at night, apart from a cough associated with a cold or chest infection in the last 12 months are prevalent among users that use combusted and vaporized methods to consume cannabis. This is particularly concerning, as evidence suggests that the presence of early symptom indicators (e.g., reporting any symptoms of cough, phlegm, or wheezing) in generally healthy young adults (between 18 and 32 years) is associated with greater decline in

lung function or impairments reflecting susceptibility to COPD later in life (Kalhan et al., 2018). Exposing the lungs to consistently inhaled carcinogenic compounds from aerosolized and combustion emissions of cannabis may compound these effects.

In the face of current health risks and susceptibility to respiratory infections associated with COVID-19 and EVALI, behaviors that increase the risk of adverse respiratory health, such as smoking and vaping are critical to examine. Evidence suggests an increased risk of positively being diagnosed with COVID-19 among youth (13-24) vaping e-cigarettes and using both e-cigarettes and cigarettes (Gaiha et al., 2020). Infection among this group may be related to multiple reasons, including the behaviors involved in repetitively bringing devices and modes of use to the mouth and face, sharing devices with others, and vulnerability to infection due to compromised lung health. These risk factors are equally shared among individuals that smoke and vape cannabis. Although there is an absence of information regarding risks of infection among cannabis users, it is important that these behaviors are considered among health care providers and warrant consideration in patient care. Finally, although the risk of EVALI remains low in Canada, and has been largely correlated to illicit products, the exact mechanisms underlying associations of cannabis vaping with respiratory health are unclear and warrant further study (Braymiller et al., 2020).

Limitations and future directions

This study adds to the limited literature on examining multiple measures of cannabis use, including quantity of various forms on respiratory symptoms of EA in Canada. In addition, it contributes to understanding sex-specific differences in consumption and differences in the prevalence of respiratory symptoms reported. Notably, findings of symptoms in the period of peak lung health in EA that smoke and vape cannabis reflects the risk of respiratory health

implications related to specific symptoms being reported before any chronic respiratory disease is typically diagnosed. Nonetheless, this study is subject to some weaknesses and limitations. Although we evaluated for potential differences stratified by sex for various correlates of respiratory symptoms associated with various cannabis consumption behaviors and exposures, we found limited evidence for significant associations related to experiencing at least one respiratory symptom separately for males and females. The extent that vaping only and dual use frequency may be negatively associated with reporting respiratory symptoms among females may be subject to type 1 error due to the small size of this study.

Future research should continue to examine various measures of consumption methods and forms of use by sex-specific and gender-specific correlates in young and heavy consumers of a larger sample size. Moreover, given the lack of research on sex-specific differences in respiratory health risks associated with various methods of combustion and vaporized forms of cannabis consumption, further research is warranted to delineate potential differences in respiratory outcomes as trends and prevalence continue to increase. Future research may benefit from examining objective measures of lung function (i.e, pulmonary tests) and employing a longitudinal research design to predict incidence of lung disease in the long-term. Moreover, recent evidence indicates that there are sex-specific factors related to physiological and biological mechanisms related to smoking topography of males and females. For example, to achieve desired intoxication effects, females need to smoke a smaller quantity of a joint, hold the smoke for short duration and inhale less deeply, than males (Matheson et al., 2020). This may have implications for differences in adverse pulmonary function changes associated with long-term cannabis smoking and vaping.

Table 6.2. Associations between cannabis consumption exposure profiles and correlates related to reporting at least one out of four respiratory symptoms in the last 12 months among male and female cannabis users.

Variables	**Classification**	**Overall (n=312) n (%) [a]**		***p-value*[b]**	**Males (n=76) n (%) [a]**		***p-value*[b]**	**Females (n = 113) n (%) [a]**		***p-value*[b]**
		Yes	No		Yes	No		Yes	No	
Age of smoking onset		17.31 (2.5)	17.35 (2.2)	.863	17.14 (2.5)	17.35 (2.3)	.634	17.42 (2.5)	17.36 (2.1)	.848
Age of vaping onset		20.63 (3.2)	20.53 (2.8)	.836	20.64 (3.5)	20.35 (2.8)	.711	20.62 (3.1)	20.65 (2.8)	.961
Cannabis user status[c]				.980			.413			.506
	Smoking only	85 (59.9)	57 (40.1)		26 (56.5)	20 (43.5)		59 (61.5)	37 (38.5)	
	Dual user	66 (40.0)	99 (60.0)		48 (64.0)	27 (36.0)		51 (56.7)	39 (43.3)	
Frequency of smoking (days)				.607			.391			.986
	Occasional (<100)	38 (62.3)	23 (37.7)		11 (64.7)	6 (35.3)		27 (61.4)	17 (38.6)	
	Frequent (≥ 100)	47 (58.0)	34 (42.0)		15 (51.7)	14 (48.3)		32 (61.5)	20 (38.5)	
Frequency of vaping/dual use (days)				.976			.457			**.211**
	Occasional (<100)	77 (61.1)	49 (38.9)		29 (61.7)	18 (38.3)		48 (60.8)	31 (39.2)	
	Frequent (≥ 100)	27 (61.4)	17 (38.6)		21 (70.0)	9 (30.0)		6 (42.9)	8 (57.1)	
Smoked tobacco 100 or more times				**.157**			**.164**			.543
	Yes	57 (70.4)	24 (29.6)		29 (74.4)	10 (25.6)		28 (66.7)	14 (33.3)	
	No	74 (60.7)	48 (39.3)		27 (60.0)	18 (40.0)		47 (61.0)	30 (39.0)	
Past 30 days tobacco smoking				**.090**			.620			**.075**
	Yes	46 (73.0)	17 (27.0)		19 (70.4)	8 (29.6)		27 (75.0)	9 (25.0)	
	No	85 (60.7)	55 (39.3)		37 (64.9)	20 (35.1)		48 (57.8)	35 (42.2)	
Primary Forms										
Herb				.645			.714			.373
	Yes	172 (61.0)	110 (39.0)		68 (61.3)	43 (38.7)		104 (60.8)	67 (39.2)	
	No	17 (56.7)	13 (43.3)		8 (66.7)	4 (33.3)		9 (50.0)	9 (50.0)	
Concentrates				.704			**.094**			**.179**
	Yes	21 (63.6)	12 (36.4)		15 (78.9)	4 (21.1)		6 (42.9)	8 (57.1)	
	No	168 (60.2)	111 (39.8)		61 (58.7)	43 (41.3)		107 (61.1)	68 (38.9)	
Hash				**.159**			**.110**			.499
	Yes	11 (78.6)	3 (21.4)		4 (100)	0 (0.0)		7 (70.0)	3 (30.0)	
	No	178 (59.7)	120 (40.3)		72 (60.5)	47 (39.5)		106 (59.2)	73 (40.8)	
Vaping liquid/oil				.864			.949			.785

	Yes	29 (61.7)	18 (38.3)		11 (61.1)	7 (38.9)		18 (62.1)	11 (37.9)	
	No	160 (60.4)	105 (39.6)		65 (61.9)	40 (38.1)		95 (59.4)	65 (40.6)	
Primary smoking methods[d]				.783			.966			.754
	Joint	67 (61.5)	42 (38.5)		28 (62.2)	17 (37.8)		39 (60.9)	25 (39.1)	
	Hand pipe	30 (62.5)	18 (37.5)		6 (60.0)	4 (40.0)		24 (63.2)	14 (36.8)	
	Bong	51 (57.3)	38 (42.7)		22 (59.5)	15 (40.5)		23 (44.2)	29 (55.8)	
Primary vaping methods[d]				**.143**			.617			**.176**
	Vape Pen	50 (61.7)	31 (38.3)		25 (67.6)	12 (32.4)		25 (56.8)	19 (43.2)	
	Dab Pen	19 (76.0)	6 (24.0)		8 (72.7)	3 (27.3)		11 (78.6)	3 (21.4)	
	Portable vaporizer	24 (52.2)	22 (47.8)		12 (57.1)	9 (42.9)		12 (48.0)	13 (52.0)	
Frequency (after COVID-19)	**Smoking**			**.043**			**.061**			.288
	Less than daily	112 (60.9)	88 (72.1)		41 (55.4)	34 (72.3)		71 (64.5)	54 (72.0)	
	Daily	72 (39.1)	34 (27.9)		33 (44.6)	13 (27.7)		39 (35.5)	21 (28.0)	
	Vaping			.581			.426			.872
	Less than daily	90 (86.5)	59 (89.4)		41 (82.0)	24 (88.9)		49 (90.7)	35 (89.7)	
	Daily	14 (13.5)	7 (10.6)		9 (18.0)	3 (11.1)		5 (9.3)	4 (10.3)	
Quantity (after COVID-19)	Herb	1.7 (2.4)	1.1 (1.9)	**.111**	2.0 (2.7)	1.5 (2.3)	.458	1.4 (2.3)	.78	**.064**
	Joint size	.70 (.41)	.64 (.45)	.582	.79 (.35)	.73 (.46)	.722	.64 (.43)	.62	.839
	Number of Joints	1.2 (1.4)	.85 (.89)	.225	1.7 (1.7)	.97 (.98)	.278	.93 (1.2)	.81	.670
	Hash[‡]	.30 (.22)	.50 (.71)	.391	.44 (.13)			.21 (1.4)	.50	.328
	Concentrate	.65 (.57)	.50 (.56)	.467	.82 (.59)	.25 (.00)	**.002**	.25 (.16)	.64	**.193**
	Vaping cartridges	1.2 (1.6)	.79 (1.2)	.343	1.7 (2.2)	.83 (1.6)	.399	.93 (1.1)	.77	.710

[a]Prevalence %; [b] *P*-values were calculated with Chi-square (categorical data) and independent t-tests (continuous data). Bold values indicate statistical significance $p < 0.20$.

[c]Data for vapers only (n=5; M:2; F:3) excluded due to small sample size.

[d]Primary methods include the top three methods reported by male and females.

[‡]=no comparison between male users that reported and did not report symptoms, because all users (n=4) reported experiencing symptoms.

Table 6.3. Predictors of reporting at least one respiratory symptom among male and female EA cannabis users.

Variables			Males		Females		Overall	
		Reference	OR	95% CI	OR	95% CI	OR	95% CI
Smoked tobacco in the last 30 days		No						-
	Yes			NA	2.58	.174-38.34	2.33	.509-10.67
Smoked tobacco 100 or more times in their life		No						-
	Yes		1.38	.509-3.75			1.55	.464-5.16
Frequency of vaping/dual use days		Occasional (<100 days)						
	Frequent (≥ 100 or more days)			NA	**.033***	.001- .885		
Smoking frequency (after COVID-19)		Less than daily						
	Daily		2.43	.880-6.70		NA	2.06	.647-6.54
Concentrate primary form		No						
	Yes		1.59	.880-6.70	.605	.042-8.72		
Primary vaping methods		Portable vaporizer						-
	Vape pen			NA	4.01	.260-61.68	.773	.228-2.63
	Dab pen			NA	7.98	.493-129.107	1.44	.212-9.72
Herb quantity		Increasing		NA	2.60	.884-7.65	.991	.754-1.30
Hosmer and Lemeshow Test (χ^2)				1.50		6.91		13.07

*p <0.05

References for Chapter 6

Aberegg, S. K., Cirulis, M. M., Maddock, S. D., Freeman, A., Keenan, L. M., Pirozzi, C. S., ... & Callahan, S. J. (2020). Clinical, Bronchoscopic, and Imaging Findings of e-Cigarette, or Vaping, Product Use–Associated Lung Injury Among Patients Treated at an Academic Medical Center. *JAMA Network Open*, *3*(11), e2019176-e2019176.

Asher, M. I., Keil, U., Anderson, H. R., Beasley, R., Crane, J., Martinez, F., ... & Stewart, A. W. (1995). International Study of Asthma and Allergies in Childhood (ISAAC): rationale and methods. *European respiratory journal*, *8*(3), 483-491. doi: 10.1183/09031936.95.08030483

Barnes, P. J. (2016). Sex Differences in Chronic Obstructive Pulmonary Disease Mechanisms. *American Journal of Respiratory and Critical Care Medicine*, 193(8), 813–814. doi: 10.1164/rccm.201512-2379ed

Behrendt, S., Wittchen, H. U., Höfler, M., Lieb, R., & Beesdo, K. (2009). Transitions from first substance use to substance use disorders in adolescence: is early onset associated with a rapid escalation?. *Drug and alcohol dependence*, *99*(1-3), 68-78.

Borgonhi, E.M., Volpatto, V.L., Ornell, F. *et al.* Multiple clinical risks for cannabis users during the COVID-19 pandemic. *Addict Sci Clin Pract* **16,** 5 (2021). https://doi.org/10.1186/s13722-021-00214-0

Braymiller, J. L., Barrington-Trimis, J. L., Leventhal, A. M., Islam, T., Kechter, A., Krueger, E. A., ... & McConnell, R. (2020). Assessment of Nicotine and Cannabis Vaping and Respiratory Symptoms in Young Adults. *JAMA network open*, *3*(12), e2030189-e2030189.

Budney, A. J., Sargent, J. D., & Lee, D. C. (2015). Vaping cannabis (marijuana): parallel concerns to e-cigs? *Addiction*, 110(11), 1699–1704. doi: 10.1111/add.13036

Chand, H. S., Muthumalage, T., Maziak, W., & Rahman, I. (2020). Pulmonary Toxicity and the Pathophysiology of Electronic Cigarette, or Vaping Product, Use Associated Lung Injury. *Frontiers in pharmacology*, *10*, 1619. https://doi.org/10.3389/fphar.2019.01619

Coates, A. L., Graham, B. L., McFadden, R. G., McParland, C., Moosa, D., Provencher, S., Road, J., & Canadian Thoracic Society (2013). Spirometry in primary care. *Canadian respiratory journal*, 20(1), 13–21. https://doi.org/10.1155/2013/615281

Cuttler, C., Mischley, L. K., & Sexton, M. (2016). Sex differences in cannabis use and effects: a cross-sectional survey of cannabis users. *Cannabis and Cannabinoid Research*, *1*(1), 166-175. doi: 10.1089/can.2016.0010

Cuttler, C., & Spradlin, A. (2017). Measuring cannabis consumption: Psychometric properties of the daily sessions, frequency, age of onset, and quantity of cannabis use inventory (DFAQ-CU). *PLoS One*, *12*(5), e0178194. https://doi.org/10.1371/journal.pone.0178194

Daniulaityte, R., Zatreh, M. Y., Lamy, F. R., Nahhas, R. W., Martins, S. S., Sheth, A., & Carlson, R. G. (2018). A Twitter-based survey on marijuana concentrate use. *Drug and alcohol dependence*, *187*, 155-159. https://doi.org/10.1016/j.drugalcdep.2018.02.033

Earleywine, M., & Barnwell, S. (2007). Decreased respiratory symptoms in cannabis users who vaporize. *Harm Reduction Journal*, 4(1), 11. doi: 10.1186/1477-7517-4-11

Earleywine, M., & Van Dam, N. T. (2010). Case studies in cannabis vaporization. *Addiction Research & Theory*, *18*(3), 243-249. doi: 10.3109/16066350902974753

Gates, P., Jaffe, A., & Copeland, J. (2014). Cannabis smoking and respiratory health: consideration of the literature. *Respirology*, *19*(5), 655-662. doi: 10.1111/resp.12298

Gaiha, S. M., Cheng, J., & Halpern-Felsher, B. (2020). Association between youth smoking, electronic cigarette use, and COVID-19. *Journal of adolescent health*, *67*(4), 519-523. https://doi.org/10.1016/j.jadohealth.2020.07.002

Ghasemiesfe, M., Ravi, D., Vali, M., Korenstein, D., Arjomandi, M., Frank, J., ... & Keyhani, S. (2018). Marijuana use, respiratory symptoms, and pulmonary function: a systematic review and meta-analysis. *Annals of internal medicine*, *169*(2), 106-115.

Greaves, L., & Hemsing, N. (2020). Sex and gender interactions on the use and impact of recreational cannabis. *International journal of environmental research and public health*, *17*(2), 509. doi:10.3390/ijerph17020509

Groeneveld, J. M., Ballering, A. V., van Boven, K., Akkermans, R. P., Olde Hartman, T. C., & Uijen, A. A. (2020). Sex differences in incidence of respiratory symptoms and management by general practitioners. *Family Practice*, *37*(5), 631-636.

Hammond D., Goodman S., Leos-Toro C., Wadsworth E., Reid JL., Hall W., Pacul R., Driezen P., George T., Rehm J., Werb D., Boudreau C., Porath A., Abramovic H., Elliot R. International Cannabis Policy Survey. August 2018

Hancox, R. J., Shin, H. H., Gray, A. R., Poulton, R., & Sears, M. R. (2015). Effects of quitting cannabis on respiratory symptoms. *European Respiratory Journal*, *46*(1), 80-87. doi: 10.1183/09031936.00034515

Hemsing, N., & Greaves, L. (2018). New challenges: developing gendered and equitable responses to involuntary exposures to electronic nicotine delivery systems (ENDS) and cannabis vaping. *International journal of environmental research and public health*, *15*(10), 2097.

Johnson, R. M., & Guttmannova, K. (2019). Marijuana use among adolescents and emerging adults in the midst of policy change: Introduction to the special issue. *Prevention Science*, *20*(2), 179-184. https://doi.org/10.1007/s11121-019-0989-7

Jones, C.B., Hill, M.L., Pardini, D.A., Meier, M.H. (2016). Prevalence and correlates of vaping

cannabis in a sample of young adults. *Psychol. Addict. Behav*. 30, 915–921. http://dx.doi.org/10.1037/adb0000217

Kalhan, R., Dransfield, M. T., Colangelo, L. A., Cuttica, M. J., Jacobs, D. R., Jr, Thyagarajan, B., Estepar, R., Harmouche, R., Onieva, J. O., Ash, S. Y., Okajima, Y., Iribarren, C., Sidney, S., Lewis, C. E., Mannino, D. M., Liu, K., Smith, L. J., & Washko, G. R. (2018). Respiratory Symptoms in Young Adults and Future Lung Disease. The CARDIA Lung Study. *American journal of respiratory and critical care medicine*, *197*(12), 1616–1624. https://doi.org/10.1164/rccm.201710-2108OC

Kazachkov, M., & Pirzada, M. (2020). Diagnosis of EVALI in the COVID-19 era. *The Lancet Respiratory Medicine*, *8*(12), 1169-1170

Lee, D. C., Crosier, B. S., Borodovsky, J. T., Sargent, J. D., & Budney, A. J. (2016). Online survey characterizing vaporizer use among cannabis users. *Drug and alcohol dependence*, *159*, 227-233. doi: 10.1016/j.drugalcdep.2015.12.020.

Leos-Toro, C., Fong, G. T., Meyer, S. B., & Hammond, D. (2020). Cannabis health knowledge and risk perceptions among Canadian youth and young adults. *Harm reduction journal*, *17*(1), 1-13. https://doi.org/10.1186/s12954-020-00397-w

Loflin, M., & Earleywine, M. (2015). No smoke, no fire: what the initial literature suggests regarding vapourized cannabis and respiratory risk. *Canadian journal of respiratory therapy: CJRT= Revue canadienne de la therapie respiratoire: RCTR*, *51*(1), 7.

LoMauro, A., & Aliverti, A. (2018). Sex differences in respiratory function. *Breathe (Sheffield, England)*, *14*(2), 131–140. https://doi.org/10.1183/20734735.000318

Machicado, J. D., Amann, S. T., Anderson, M. A., Abberbock, J., Sherman, S., Conwell, D. L., Cote, G. A., Singh, V. K., Lewis, M. D., Alkaade, S., Sandhu, B. S., Guda, N. M., Muniraj, T., Tang, G., Baillie, J., Brand, R. E., Gardner, T. B., Gelrud, A., Forsmark, C. E., Banks, P. A., … Yadav, D. (2017). Quality of Life in Chronic Pancreatitis is Determined by Constant Pain, Disability/Unemployment, Current Smoking, and Associated Co-Morbidities. *The American journal of gastroenterology*, *112*(4), 633–642. https://doi.org/10.1038/ajg.2017.42

Martinasek, M. P., McGrogan, J. B., & Maysonet, A. (2016). A systematic review of the respiratory effects of inhalational marijuana. *Respiratory care*, *61*(11), 1543-1551. doi: 10.4187/respcare.04846

Matheson, J., Sproule, B., Di Ciano, P., Fares, A., Le Foll, B., Mann, R. E., & Brands, B. (2020). Sex differences in the acute effects of smoked cannabis: evidence from a human laboratory study of young adults. *Psychopharmacology*, *237*(2), 305-316. doi: http://dx.doi.org/10.1007/s00213-019-05369-y

Morris, M. A., Jacobson, S. R., Kinney, G. L., Tashkin, D. P., Woodruff, P. G., Hoffman, E. A., ... & Bowler, R. P. (2018). Marijuana use associations with pulmonary symptoms and function in tobacco smokers enrolled in the Subpopulations and Intermediate Outcome Measures in COPD Study (SPIROMICS). *Chronic Obstructive Pulmonary Diseases: Journal of the COPD Foundation*, *5*(1), 46.

Osborne, G. B., & Fogel, C. (2016). Perspectives on Cannabis Legalization Among Canadian Recreational Users. *Contemporary Drug Problems*, 44(1), 12-31. doi:10.1177/0091450916670393

Rotermann, M. (2020). What has changed since cannabis was legalized. *Health Rep*, *31*(2), 11-20. doi: https://www.doi.org/10.25318/82-003-x202000200002-eng

Russell, C., Rueda, S., Room, R., Tyndall, M., & Fischer, B. (2018). Routes of administration for cannabis use - basic prevalence and related health outcomes: A scoping review and synthesis. *International Journal of Drug Policy*. 1, 87-96. doi.org/10.1016/j.drugpo.2017.11.008

Ribeiro, L. I., & Ind, P. W. (2016). Effect of cannabis smoking on lung function and respiratory symptoms: a structured literature review. *NPJ primary care respiratory medicine*, *26*(1), 1-8.

Ribeiro, L., & Ind, P. W. (2018). Marijuana and the lung: hysteria or cause for concern? *Breathe*, 14(3), 196–205. doi: 10.1183/20734735.020418

Stone, A. L., Becker, L. G., Huber, A. M., & Catalano, R. F. (2012). Review of risk and protective factors of substance use and problem use in emerging adulthood. *Addictive Behaviors*, 37(7), 747–775. doi: 10.1016/j.addbeh.2012.02.014

Taylor, D. R., Poulton, R., Moffitt, T. E., Ramankutty, P., & Sears, M. R. (2000). The respiratory effects of cannabis dependence in young adults. *Addiction*, 95(11), 1669–1677. doi: 10.1046/j.1360-0443.2000.951116697.x

Troutt, W. D., & DiDonato, M. D. (2017). Carbonyl compounds produced by vaporizing cannabis oil thinning agents. *The Journal of Alternative and Complementary Medicine*, *23*(11), 879-884. doi: 10.1089/acm.2016.0337

Van Dam, N. T., & Earleywine, M. (2010). Pulmonary function in cannabis users: support for a clinical trial of the vaporizer. *International Journal of Drug Policy*, *21*(6), 511-513. https://doi.org/10.1016/j.drugpo.2010.04.001

Van Der Pol, P., Liebregts, N., De Graaf, R., Korf, D. J., van den Brink, W., & van Laar, M. (2013). Predicting the transition from frequent cannabis use to cannabis dependence: a three-year prospective study. *Drug and Alcohol Dependence*, *133*(2), 352-359. https://doi.org/10.1016/j.drugalcdep.2013.06.009

Wadsworth, E., & Hammond, D. (2019). International differences in patterns of cannabis use among youth: prevalence, perceptions of harm, and driving under the influence in Canada, England & United States. *Addictive behaviors*, *90*, 171-175.

Chapter 7. Conclusion

7.1 Overview

This thesis sought to examine cannabis consumption behaviors of EA in Canada in relation to political and public health developments over time. Specifically, the change in the political landscape of legalizing recreational cannabis use in Canada (October 2018), the declaration of the 'silent' epidemic of 'e-cigarette or vaping product use associated lung injuries' (EVALI; November, 2019), and following the unprecedented pandemic related to the spread of SARS-CoV2 disease or 'COVID-19' (March, 2020). In addition, changes in cannabis consumption were analyzed based on sex-specific differences (male or female), considering the unique physiological mechanisms, impact of gender social norms, and cultural relations, that influence risk behaviors and health outcomes in each population (Greaves & Hemsing, 2020).

For Canadians, the subsequent public health developments that have occurred following the legalization of cannabis, has influenced the risk of increased substance use and susceptibility to respiratory health risks for the population within a relatively short time span. The EVALI epidemic and COVID-19 pandemic are challenging health risks to navigate, in the current climate of cultural normalization surrounding cannabis use for high risk and consumer groups. In the face of these developments, by virtue of legal access, and high prevalence rate of cannabis consumption, EA have been considered a central at-risk population to monitor as a cohort that is vulnerable to increased consumption following legalization, experimenting with novel means of consumption (i.e., vaping), and substance misuse as a means of coping and negating feelings of boredom during a pandemic. In addition, they have been among the highest affected cohort by respiratory infections associated with EVALI and COVID-19.

Accordingly, the primary research objective of this study was to better understand the cannabis consumption behaviors of EAs in relation to specific measures of consumption (frequency and quantity) by sex, and how they may be affected by political and societal (e.g., public health crisis) developments. The second and third objective was to determine whether there are significant sex-specific differences in determinants of respiratory symptoms in relation to cannabis consumption behaviors of EA and sex-specific patterns of consumption (method, mode, form, frequency, quantity). These objectives have been met in manuscript one, two, and three, respectively.

Summary of findings

Manuscript one addressed changes in self-reported frequency trends of inhaled routes of cannabis consumption (i.e., smoking and vaping) following the legalization of recreational cannabis use in Canada, the EVALI epidemic, and COVID-19 pandemic, among male and female EA in Canada. Our findings suggest that among EA, these issues exert an impact on smoking and vaping patterns of cannabis consumption by increasing rather than decreasing consumption frequency. In addition, an increase in average smoking and vaping frequency was seen before and after each time period for males and females. Consistent with other research (Van Laar et al., 2020) is that cannabis users smoking at a higher frequency (weekly or daily) may increase their use, and thus demonstrate an easier transition to dependency, as users are likely to take refuge in cannabis use to cope with psychosocial stressors (e.g., home confinement, depression, fear of infection) during the COVID-19 pandemic. Small changes in average increases in frequency over time indicate gradual and incremental increases in use from one frequency measure to another. This suggests that changes in consumption, particularly an increase may occur gradually over time, rather than abruptly.

In addition, inconsistent frequency of consumption is most likely to represent occasional users - EA are likely to engage in infrequent opportunities where cannabis is available. For EA, the current cultural environment of widespread cannabis consumption is likely to challenge abstinence and require more conscious effort to stop from taking opportunistic "puffs" and sharing cannabis with peers (Hathaway et al., 2018). Furthermore, as addressed in manuscript two, an increasing continuous trend in average quantity of specific forms of cannabis consumed was observed. Quantity of consumption is a critical independent measure in understanding the cumulative health risks of cannabis (Zeisser et al., 2012). Our findings were able to provide average measures of consumption of various cannabis forms, including herb in its independent form, in the size of a joint, joint quantity, other extracts, including, hash, concentrates and vaping oil. These findings aid in establishing an acceptable standardized measuring tool of consumption which can be used to examine cannabis-related harm and cross-cultural comparisons. Overall, our findings suggest that, frequency and quantity simultaneously increase over time, and thus cumulative exposure levels based on both measures are important to examine.

There was limited awareness of EVALI in our study and thus corresponding expected changes (a decrease in vaping frequency) was not observed. Although a small proportion of users indicated that EVALI had changed their consumption and negatively influenced their vaping behavior. In Canada, the rate of EVALI cases have been substantially low compared to other regions (e.g., USA and UK), and have largely been attributed to products obtained from informal sources (Ellington et al., 2020; King et al., 2020). Although it is hopeful to perceive that public health efforts to transmit information regarding EVALI would reach and influence the most at-risk populations. In addition, as public health efforts continue to eradicate vaping products associated with EVALI cases, such as vitamin E acetate, the cause of EVALI has been

considered to be multifactorial, and the incidence of respiratory outcomes may continue due to product characteristics (temperature of heating elements, forms of cannabis, and device variety) (Braymiller et al., 2020).

As a substance that has traditionally been administered through routes of inhalation, the examination of respiratory risks associated with smoking cannabis has been compared against the respiratory health risks associated with tobacco use and has found similar adverse respiratory outcomes (Ghasemeisfe et al., 2018; Ribeiro & Ind, 2016). Although the recent popularity of electronic vaping devices, which has influenced the uptake of dual use (smoking and vaping) requires further understanding to confirm the benefits compared to the harm associated with combustion vs vaporization.

In manuscript three, correlates of respiratory symptoms were examined for various exposures of cannabis consumption (method, frequency, quantity, mode, form). Consistent with previous research, we found that cannabis users experienced multiple respiratory symptoms linked to chronic bronchitis, such as dry cough, phlegm production and wheezing (Ghasemiesfe et al., 2018; Martinasek et al., 2016). A significant difference for dry cough and sex was found, with males more likely to report experiencing dry cough than females. This may be correlated to the quantity and frequency of consumption, as well as the high prevalence of dual use among males. However, lifetime frequency patterns of vaping only/dual use were protective of reporting at least one symptom among females only. These findings suggest the need for further research that examines various cannabis consumption profiles separately by sex. Future research should examine these factors in a larger representative population of EA, and respiratory health risks associated with exclusively smoking, exclusively vaping, and importantly dual use.

7.2 Strengths and limitations

The current study is among the first to investigate specific trends of cannabis consumption in relation to quantity measures of various cannabis forms and changes in multiple frequency measures of EA in Canada, in relation to successive political (i.e., legalization of cannabis) and public health developments (EVALI and COVID-19) over time. In addition, it contributes to the paucity of research examining the effects of various cannabis consumption exposure profiles associated with respiratory health status based on sex-specific differences in consumption, specifically the route of inhalation (smoking or vaping), method and apparatuses used, and the corresponding forms of cannabis smoked or vaped. The impact of changing contexts in relation to political amendments, unknown long-term health effects of various cannabis products, as well as emerging public health risks, are important factors in understanding if widespread recommendations and coverage of developments including EVALI and COVID-19 effectively influence protective health behaviors.

A quantitative online-survey was designed to obtain self-reported information on cannabis consumption profiles, measures of consumption, and respiratory health status. The development of the survey is an important methodological contribution to cannabis research, guided by conceptual frameworks, including the LCHD framework and HBM. Validated questionnaires were also applied to examine a wide range of variables and measurements of cannabis consumption that can be used to further elucidate the predictors of cannabis consumption and respiratory health risks. In addition, the survey was a cost- and time-efficient method to reach the desired population in a short period of time. Social media platforms (Facebook and Twitter) were used to disseminate the survey, which has demonstrated to be effective in recruiting participants for research on cannabis use (Lee et al., 2016). Further research may benefit from using these platforms to facilitate rapid, repeated assessment of

developing trends in cannabis consumption. In addition, web-based surveys have been proven to be effective in obtaining information from students on taboo topics such as substance use, due to the remoteness and anonymity provided by the internet and from behind a screen (Daniulaityte et al., 2018).

It is important to note that this study is not without limitations. First, this research used an exploratory cross-sectional study design. This method was applied due to the limited evidence-base related to the impact of the investigated major political changes worldwide, natural occurrences (COVID-19), and first-time rapid rates of lung injuries (EVALI), on cannabis consumption behaviors. Although cross-sectional surveys can be highly effective, they are subject to limitations based on the time data is collected and inability to draw causal inferences. Cross-sectional study designs can identify prevalence, but they cannot report on incidence or relative risk (Setia, 2016). In addition, the survey was retrospective and therefore did not collect data on the temporal relationship between legalization, and EVALI. Furthermore, all measures obtained were self-reported, imposing the subjectivity of social desirability bias. Measures of consumption provided are also subject to recall bias, impeding on accuracy of reported past-year quantity and frequency patterns.

Other limitations include complications related to measuring the nature of cannabis consumption. For example, determination of a specific universal definition for each form, mode, and method of consumption, in addition to the wide range of measurements for frequency and quantity patterns makes it difficult to examine universal effects. Specifically, definitions vary for methods of consumption – the term ‘spliff’, ‘joint’ and ‘blunt’ can be used interchangeably to indicate a rolled cannabis cigarette. Although a spliff is considered to contain a mixture of cannabis and tobacco whereas a joint refers to a roll containing exclusively dried herb, and a

blunt contains a higher quantity of dried herb (Russel et al., 2018). Moreover, the definition of novel techniques of using concentrate cannabis forms through 'dabbing' has been considered both a form of vaping and smoking, and similarly compared to using a bong. Even though the survey specifically defined each method and form of consumption, the varied definitions of cannabis behaviors, may have led to some uncertainty for individuals to indicate their method of consumption (i.e., vaping or smoking). In addition, this survey was intended to target individuals 18 to 29 years of age, however, it is possible that some respondents that completed the survey were under the age of 18 or older than the age of 29.

Moreover, although cannabis consumption and substance use patterns are influenced by gender-specific factors, which comprises of the "social, environmental, cultural, and behavioral factors and choices that influence a person's self-identity and health" (Clayton & Tannenbaum, 2016), this thesis examined changes in cannabis consumption measures (frequency and quantity) and behavioral profiles (mode, form, method) in relation to specified sex-characteristics (male or female). This may create bias in determining gender-specific differences in consumption behaviors, as consumption may differ in relation to gender-identity based factors. It is important to caution interpreting differences in consumption by sex, as individual variability in masculinity and femininity are subjective to enactment and perceived identity (Greaves & Hemsing, 2020). For the purposes of this research, sex of study participants was used in analysis as there was limited variation between gender-identity and sex identified at birth of the study sample. In addition, sex-specific characteristics are important in differentiating health-risks in relation to disease development, based on physiological and biological factors, which was relevant in examining respiratory symptoms of cannabis users.

What may have strengthened the analysis of respiratory health outcomes in this study, is the ability to assess objectives measures of pulmonary function. Although this study initially included an objective to collect data on pulmonary function of cannabis users, this could not be authorized due to the declaration of the COVID-19 pandemic, in order to minimize risk of exposure and spread of infections.

Previous studies examining the effects of cannabis smoking on respiratory health have used spirometry to measure the adverse effects of cannabis on pulmonary function, and the associated progression of pulmonary disease by measuring FEV_1/FVC; the most reliable measure of airflow obstruction and diagnosis of COPD (Ribeiro & Ind, 2016). However, the research on measures of pulmonary function associated with smoking cannabis is insufficient, and the evidence is mixed regarding independent assessments of spirometric indices to conclude effects on pulmonary obstruction (Ghasemiesfe et al., 2018; Ribeiro & Ind, 2016). Future research on pulmonary function may help to address the bronchodilation effects of THC and increased FVC (Ribeiro & Ind, 2016). In addition, previous research has been stunted due to a high application of cross-sectional study designs, which may be improved by implementing longitudinal research over longer follow-up times. Furthermore, emerging trends in cannabis consumption in Canada, indicating an increase in daily consumption, and unknown effects of vaping among younger populations may have implications in the long-term, thus necessitating further research on pulmonary effects of cannabis consumption.

7.3 Implications for future policies and interventions

Although research efforts continue to examine trends in consumption prevalence, analyses focused solely on recording changes in prevalence rates while necessary, limits a comprehensive understanding of the potential impacts of legalization on consumption trends

(Leos-Toro et al., 2020; Rotermann, 2019). Future research should indicate the predictors of change associated with frequency of both smoking and vaping, and other critical measures, including quantity of cannabis forms used across a larger representative population of cannabis users. A mixed-method study design that allows for examining individual-level experiences for reasons associated with changes in consumption, and emerging themes that may lead to increase or decrease consumption, in relation to social and environmental contextual changes is warranted. This may facilitate the understanding of individual-level characteristics associated with patterns of consumption, and assessment of different motives for use. In addition, using physical equivalency conversion values to measure quantity of various cannabis forms (Callaghan et al., 2020), while also controlling for other factors such as THC content in clinical-based studies may improve understanding of cannabis-related effects.

Among EA, a range of adverse social, mental and physiological consequences have been linked to chronic cannabis use, interfering with optimal development during this period, such as substance misuse and addiction (Iede et al., 2017; Stone et al., 2012), cognitive impairment, altered brain development (Gilman et al., 2014), and overall decreases in subjective health (Ames et al., 2020). Despite these findings, the lack of informative literature and nascent health policy guidelines with respect to exposure and intoxication levels determining a concrete definition of 'problematic use', has influenced minimal risk perception among this population (Mostaghim & Hathaway, 2013). In addition, the easing of regulations and longstanding legislation regarding medicinal use over the past two decades may have persuaded the notion of self-medication of various psychiatric ailments among EA (Volkow et al., 2014). Although, doctors express their hesitation in prescribing medicinal use due to a lack of determination of whether the "benefits exceed the harm" (Ng et al., 2021). In the field of psychiatry, medicinal

cannabis is emerging as a widely used prescription of symptoms such as depression, PTSD and improving sleep. However, the effectiveness of cannabinoid therapeutics is nascent, with evidence indicating no benefits for depression, especially from high-THC products (Sarris et al., 2020). Perhaps an important consideration is cautioning from rapid interventions of cannabis as a therapeutic assessment of a range of psychiatric disorders, especially high-THC products that can exacerbate anxiety or psychotic disorders and increase the risk of cannabis use disorder (Sarris et al., 2020).

Besides the potential health impacts related to the pharmacological properties of the plant, the methods used to achieve desired effects, specifically through combustion and vaping, represent key risk factors for developing respiratory symptoms (Braymiller et al., 2020; Ghasemiesfe et al., 2018; Ribeiro & Ind, 2018). In addition to the nuanced efforts of curtailing the use of tobacco products, the legalization of cannabis has become another long fight for decades to come in understanding long-term health effects. While some evidence stands to illustrate that, aerosols produced by vaping cannabis products may reduce the risk of harm to the lungs over a short-term of use, compared to inhaling cannabis products passed through combustion, the accumulation of harm inherent in tobacco smoke took many years to surface (Budney et al., 2015). The escalation of the cultural vaping trend may be a harbinger of unknown long-term health effects, as similarly experienced with tobacco, and since research remains limited on the overall effects of cannabis smoking on lung health (Budney et al., 2015; Ghasemiesfe et al., 2018).

In light of this evidence, it is critical to examine measures of cannabis exposure and behaviors of consumption in relation to routes and methods of use (smoking or vaping), to develop a better understanding of harm-reduction guidelines. The complexity of physiological

effects and diverse profiles of cannabis consumption has made it to difficult to assess harm-reduction guidelines in relation to sex-specific differences. For example, females experience the same level of subjective and physiological effects as males at lower blood cannabinoid concentrations (Matheson et al., 2020). Thus, it is critical for stringent lower-risk cannabis use guidelines to be developed and are improved for target interventions for males and females, considering differences in sex-specific effects, and gender-differences in consumption (Lee et al., 2020). Canada's lower-risk cannabis use guidelines (LRCUG) highlight that clinical research should also consider that cannabis use risks will vary in their likelihood and severity with user characteristics, use patterns, and product qualities (Fischer et al., 2017). Indeed, high THC-content products are generally associated with higher risks of various (acute and chronic) mental and behavioral problem outcomes (Chan et al., 2017; Volkow et al., 2014). Thus, consumers are encouraged to considers factors such as the nature and composition of the products before using highly concentrated forms.

Vulnerable populations aside from EA that are specifically considered special-risk populations include, subgroups of individuals that may be predisposed to mental health problems, substance use disorders, and use during pregnancy. Other evidence-based lower-risk recommendations developed to inform health-risks and to educate the public include, avoiding inhalation methods, controlling frequency and intensity of use, and combining high-risk exposures, such as using high THC content on a daily basis. Furthermore, due to the effects of cannabis on cognitive functions, refraining from driving after intoxication is recommended – although, unlike for alcohol, a standard THC concentration has not been implemented for defining "impairment" (Lake & Kerr, 2017). Such health-risks may be improved by measuring

THC content and associated intoxication levels and length of intoxication in clinical studies that look at sex-specific physiological differences in effects.

Finally, although smoking or vaping cannabis has not been strongly indicated as an independent risk factor for COVID-19, there are many other factors that can increase the risk of susceptibility and severity of infection, such as compromised respiratory and immune function (Borgonhi et al., 2021; Dubey et al., 2020). Future research must be directed to delineate more stringent associations between smoking and vaping status of cannabis, associated comorbidities and COVID-19, and possibility of transmission of sharing cannabis products that may have led to infection.

7.4 Conclusion

Radical policy changes and public health developments related to acute and widespread outbreaks of respiratory illnesses have been historically unprecedented yet may periodically emerge with potential long-term implications on behavioral and societal changes. Specifically, such developments occurring in succession, may merge to contribute and increase the risk of respiratory health outcomes related to maladaptive health behaviors (e.g., substance use). This cross-sectional exploratory study contributes to understanding how cannabis consumption behaviors and trends of EA in Canada may be influenced by public health risks and political changes – as potential salient predictors of increased consumption over time. In addition, it adds to understanding differences in consumption of various cannabis exposure profiles (frequency, quantity, method, mode, and form) in relation to sex, and on respiratory health outcomes. Although, there is a need for more research examining objective measures of respiratory function in relation to various cannabis exposure profiles. In addition, as mental health complications are likely to increase as a result of the heavy psychological burdens placed on individuals from the

COVID-19 pandemic, further monitoring of cannabis consumption among vulnerable populations, where the usage of this substance for self-treatment of psychiatric and mental health symptoms is high, is needed. The findings of this study may serve in generating discourse related to the implications of political amendments, public health risks and pandemics on cannabis use trends, and the effectiveness of imminent interventions geared towards cannabis misuse and ham-reduction.

References for Chapter 7

Ames, M. E., Leadbeater, B. J., Merrin, G. J., & Thompson, K. (2020). Patterns of marijuana use and physical health indicators among Canadian youth. *International journal of psychology*, *55*(1), 1-12. doi.org/10.1002/ijop.12549

Braymiller, J. L., Barrington-Trimis, J. L., Leventhal, A. M., Islam, T., Kechter, A., Krueger, E. A., ... & McConnell, R. (2020). Assessment of Nicotine and Cannabis Vaping and Respiratory Symptoms in Young Adults. *JAMA network open*, *3*(12), e2030189-e2030189. doi:10.1001/jamanetworkopen.2020.30189

Borgonhi, E. M., Volpatto, V. L., Ornell, F., Rabelo-da-Ponte, F. D., & Kessler, F. H. P. (2021). Multiple clinical risks for cannabis users during the COVID-19 pandemic. *Addiction Science & Clinical Practice*, *16*(1), 1-4. https://doi.org/10.1186/s13722-021-00214-0

Callaghan, R. C., Sanches, M., Benny, C., Stockwell, T., Sherk, A., & Kish, S. J. (2019). Who consumes most of the cannabis in Canada? Profiles of cannabis consumption by quantity. *Drug and alcohol dependence*, *205*, 107587. https://doi.org/10.1016/j.drugalcdep.2019.107587

Chan, G. C., Hall, W., Freeman, T. P., Ferris, J., Kelly, A. B., & Winstock, A. (2017). User characteristics and effect profile of Butane Hash Oil: An extremely high-potency cannabis concentrate. *Drug and Alcohol Dependence*, 178, 32–38. doi: 10.1016/j.drugalcdep.2017.04.014

Clayton, J. A., & Tannenbaum, C. (2016). Reporting sex, gender, or both in clinical research?. *Jama*, *316*(18), 1863-1864. doi:10.1001/jama.2016.16405

Cooper, Z. D., & Haney, M. (2014). Investigation of sex-dependent effects of cannabis in daily cannabis smokers. *Drug and alcohol dependence*, *136*, 85–91. https://doi.org/10.1016/j.drugalcdep.2013.12.013

Daniulaityte, R., Zatreh, M. Y., Lamy, F. R., Nahhas, R. W., Martins, S. S., Sheth, A., & Carlson, R. G. (2018). A Twitter-based survey on marijuana concentrate use. *Drug and alcohol dependence*, *187*, 155-159. https://doi.org/10.1016/j.drugalcdep.2018.02.033

Dubey, M. J., Ghosh, R., Chatterjee, S., Biswas, P., Chatterjee, S., & Dubey, S. (2020). COVID-19 and addiction. *Diabetes & metabolic syndrome*, *14*(5), 817–823. https://doi.org/10.1016/j.dsx.2020.06.008

Fischer, B., Russell, C., Sabioni, P., Van Den Brink, W., Le Foll, B., Hall, W., ... & Room, R. (2017). Lower-risk cannabis use guidelines: a comprehensive update of evidence and recommendations. *American journal of public health*, *107*(8), e1-e12. doi:10.2105/ AJPH.2017.303818)

Ghasemiesfe, M., Ravi, D., Vali, M., Korenstein, D., Arjomandi, M., Frank, J., ... & Keyhani, S.

(2018). Marijuana use, respiratory symptoms, and pulmonary function: a systematic review and meta-analysis. *Annals of internal medicine*, *169*(2), 106-115. doi:10.7326/M18-0522

Gilman, J. M., Kuster, J. K., Lee, S., Lee, M. J., Kim, B. W., Makris, N., ... & Breiter, H. C. (2014). Cannabis use is quantitatively associated with nucleus accumbens and amygdala abnormalities in young adult recreational users. *Journal of Neuroscience*, *34*(16), 5529-5538. doi: https://doi.org/10.1523/JNEUROSCI.4745-13.2014

Greaves, L., & Hemsing, N. (2020). Sex and Gender Interactions on the Use and Impact of Recreational Cannabis. International Journal of Environmental Research and Public Health, 17(2), 509. doi:10.3390/ijerph17020509

Hathaway, A. D., Mostaghim, A., Erickson, P. G., Kolar, K., & Osborne, G. (2018). "It's Really No Big Deal": The Role of Social Supply Networks in Normalizing Use of Cannabis by Students at Canadian Universities. *Deviant Behavior*, 39(12), 1672–1680. doi: 10.1080/01639625.2017.1411047

Hyman, S. M., & Sinha, R. (2009). Stress-related factors in cannabis use and misuse: implications for prevention and treatment. *Journal of substance abuse treatment*, *36*(4), 400–413. https://doi.org/10.1016/j.jsat.2008.08.005

Iede, M. A., Nunn, K., Milne, B., & Fitzgerald, D. A. (2017). The consequences of chronic cannabis smoking in vulnerable adolescents. Paediatric Respiratory Reviews,24, 44-53. doi:10.1016/j.prrv.2016.11.001

Lake, S., & Kerr, T. (2017). The Challenges of Projecting the Public Health Impacts of Marijuana Legalization in Canada Comment on "Legalizing and Regulating Marijuana in Canada: Review of Potential Economic, Social, and Health Impacts". *International journal of health policy and management*, *6*(5), 285–287. https://doi.org/10.15171/ijhpm.2016.124

Lee, C. R., Lee, A., Goodman, S., Hammond, D., & Fischer, B. (2020). The Lower-Risk Cannabis Use Guidelines'(LRCUG) recommendations: How are Canadian cannabis users complying?. *Preventive Medicine Reports*, *20*, 101187.

Leos-Toro, C., Fong, G. T., Meyer, S. B., & Hammond, D. (2020). Cannabis health knowledge and risk perceptions among Canadian youth and young adults. *Harm reduction journal*, *17*(1), 1-13. https://doi.org/10.1186/s12954-020-00397-w

Matheson, J., Sproule, B., Di Ciano, P., Fares, A., Le Foll, B., Mann, R. E., & Brands, B. (2020). Sex differences in the acute effects of smoked cannabis: evidence from a human laboratory study of young adults. *Psychopharmacology*, *237*(2), 305-316. doi: http://dx.doi.org/10.1007/s00213-019-05369-y

Ng, J. Y., Gilotra, K., Usman, S., Chang, Y., & Busse, J. W. (2021). Attitudes toward medical

cannabis among family physicians practising in Ontario, Canada: A qualitative research study. CMAJ Open, 9(2). doi:10.9778/cmajo.20200187

Rotermann, M. (2019). Analysis of trends in the prevalence of cannabis use and related metrics in Canada. *Health reports*, *30*(6), 3-13.

Ribeiro, L. I., & Ind, P. W. (2016). Effect of cannabis smoking on lung function and respiratory symptoms: A structured literature review. Npj Primary Care Respiratory Medicine, 26(1). doi:10.1038/npjpcrm.2016.71

Ribeiro, L., & Ind, P. W. (2018). Marijuana and the lung: Hysteria or cause for concern? Breathe, 14(3), 196-205. doi:10.1183/20734735.020418

Sarris, J., Sinclair, J., Karamacoska, D. et al. Medicinal cannabis for psychiatric disorders: a clinically-focused systematic review. BMC Psychiatry 20, 24 (2020). https://doi.org/10.1186/s12888-019-2409-8

Setia M. S. (2016). Methodology Series Module 3: Cross-sectional Studies. *Indian journal of dermatology*, *61*(3), 261–264. https://doi.org/10.4103/0019-5154.182410

Stone, A. L., Becker, L. G., Huber, A. M., & Catalano, R. F. (2012). Review of risk and protective factors of substance use and problem use in emerging adulthood. *Addictive Behaviors*, 37(7), 747–775. doi: 10.1016/j.addbeh.2012.02.014

Van Laar, M. W., Oomen, P. E., van Miltenburg, C., Vercoulen, E., Freeman, T. P., & Hall, W. D. (2020). Cannabis and COVID-19: Reasons for Concern. *Frontiers in psychiatry*, *11*, 601653. https://doi.org/10.3389/fpsyt.2020.601653

Volkow, N. D., Baler, R. D., Compton, W. M., & Weiss, S. R. (2014). Adverse health effects of marijuana use. *New England Journal of Medicine*, *370*(23), 2219-2227. doi:10.1056/NEJMra1402309.

Zeisser, C., Thompson, K., Stockwell, T., Duff, C., Chow, C., Vallance, K., ... & Lucas, P. (2012). A 'standard joint'? The role of quantity in predicting cannabis-related problems. *Addiction Research & Theory*, *20*(1), 82-92. doi: 10.3109/16066359.2011

APPENDICES

Appendix A. Participant Sociodemographic Information

Table A1. Sociodemographic characteristics of study population that smoked and / or vaped cannabis in the last 12 months (N=312).

Variable	Classification	Overall	
		n	%
Age (current)	Years (mean ± SD)	22.8 ± 3.35	
Sex			
	Male	123	39.4
	Female	189	60.6
Gender			
	Male	123	39.7
	Female	169	54.5
	Transgender	8	2.6
	Other	10	3.2
	Prefer not to say	2	.6
Education			
	High school diploma or less	77	24.7
	College diploma/certificate	61	19.6
	Bachelor's degree	161	51.6
	Master's degree	13	4.2
Ethnicity			
	White	181	58.2
	South Asian	30	9.6
	West Asian	15	4.8
	Mixed/interracial	29	9.3
	Chinese	7	2.2
	Black	17	5.4
	Filipino	11	3.5
	Latin American	7	2.2
	Arab	2	.6
	Southeast Asian	2	.6
	First Nations	6	1.9
	Other	4	1.3
	Prefer not say	1	.3
Household income			
	Less than $20,000	19	8.9
	$20,000 to less than $30,000	16	7.5
	$30,000 to less than $40,000	20	9.3
	$40,0000 to less than $50,000	19	8.9
	$50,000 to less than $60,0000	12	5.6
	$60,000 to less than $70,000	14	6.5
	$70,000 to less than $80,000	16	7.5
	$80,000 to less than $90,000	7	3.3
	$90,000 to less than $100,000	15	7.0

	More than $100,000	76	35.5
	I do not know	56	17.9
	Prefer not to say	14	4.5
Personal income			
	Less than $20,000	168	58.3
	$20,000 to less than $30,000	43	13.8
	$30,000 to less than $40,000	22	7.6
	$40,0000 to less than $50,000	12	4.2
	$50,000 to less than $60,0000	17	5.9
	$60,000 to less than $70,000	9	3.1
	$70,000 to less than $80,000	6	2.1
	$80,000 to less than $90,000	6	2.1
	$90,000 to less than $100,000	2	.7
	More than $100,000	3	1.0
	I do not know	10	3.2
	Prefer not to say	14	4.5
Current living situation			
	Parent(s)/Guardians(s)	153	49.7
	Partner/Spouse	48	15.6
	Roommate(s)	60	19.5
	Family/Children	15	4.9
	I live alone	28	9.1
	Other	4	1.3

Appendix B. Survey

Cannabis Consumption Profiles of Emerging Adults in Canada

Section 1:
Thank you for your interest in this research study and for your consideration in taking this survey.

You will find a brief description of this research study in the next page.

We will require your explicit consent to participate in this research. After reading the consent form, if you do not wish to participate in the study, you may exit your browser or choose 'no'.

Section 2: Description of Study

If you are a young adult between 18-29 years old who has smoked or vaped cannabis in the last 12 months, you are invited to participate in this research study.

Purpose:

This research study examines how profiles of cannabis consumption are influenced by specific events such as legalization, vaping associated lung injury outbreaks, and the COVID-19 pandemic. Surveillance of perceptions and behavioral responses of individuals during pandemics provides useful information for health risk communication.

Procedures:

If you agree to participate in this study, you will be asked to complete this online survey, which will take approximately 20-25 minutes of your time. You may withdraw from the research study by not starting or finalizing the survey. If you wish to STOP the survey and withdraw your participation, you may do so at any time during the survey by closing the browser. Your information will not be saved unless you click "Submit" at the end of the survey.

To withdraw prior to submitting your responses, simply close the online browser and do not hit submit. Once you have submitted your survey we can only withdraw your data if you have provided us with your email address during the study. The deadline for withdrawing your data is August 31, 2020, following which we will have already begun analysis of the data. Please send us an email prior to that date if you do decide you want to withdraw your responses from the study data.

Some questions marked with an asterisk (*) require an answer before moving on to the next question. As a participant, you have the choice not to answer any questions that may cause distress or discomfort. Your participation in this study is voluntary and you may partake in only those aspects of the study in which you feel comfortable. You may leave the study at any time without suffering any consequences.

Section 3: Additional Information

Potential Risks and Benefits:

There is a potential risk that you may feel some discomfort while answering questions regarding your cannabis consumption or about COVID-19 and specific events such as the outbreak of vaping associated lung injuries, and legalization. However, if at any time you feel uncomfortable answering a question, you are not obligated to answer. As a participant you may not directly benefit from this study, however, your contribution toward completing the survey can help with developing recommendations and provide a foundation to public health risk and harm reduction guidelines. You may personally benefit by becoming aware of your respiratory health, and how to navigate through this pandemic.

Use and Storage of Data:

We will remove any identifying information from the data that we store. If you do provide us with an email address to participate in any future longitudinal studies, we will keep a code that allows us to identify your data in a separate encrypted folder than from your personal information. The aggregated data will be shared with members of this study research team. The results of the survey will be kept for a 2-year period and then destroyed (deleted).

Confidentiality:

Your privacy shall be respected. No information about your identity will be shared or published without your permission, unless required by law. Confidentiality will be provided to the fullest extent possible by law, professional practice, and ethical codes of conduct. This research study includes the collection of demographic data which will be aggregated (not individually presented) in an effort to protect your anonymity. Despite best efforts it is possible that your identity can be determined even when data is aggregated, however, due to the anonymity of the data the risk of this is very low.

Compensation, Reimbursement, Incentives:

No incentives, compensation, or reimbursement action will take place for the successful completion of this study.

Debriefing and Dissemination of Results:

If you wish to be informed of the results of this study please follow our Facebook page: @OntarioTechCCPStudy via the following link: (to be provided).

This study has been reviewed by the Ontario Tech University Research Ethics Board [insert assigned REB #] on [insert date].

The next section will seek your consent to participate in this study. If you agree, the following sections of the survey will focus on demographic information, cannabis consumption profiles, changes in cannabis consumption profiles, social perceptions of cannabis consumption, and respiratory health status.

Section 4: Consent

Name of Principal Investigator (PI): Dr. Caroline Barakat
PI's contact number(s)/email(s): Caroline.Barakat@ontariotechu.ca/ 905.721.8668 ext. 2173
Names(s) of Co-Investigator(s), Faculty Supervisor, Student Lead(s), etc., and email(s):

Student Lead: Susan Yousufzai, susan.yousufzai@ontariotechu.net
Faculty Supervisor: Dr. Adam Cole, adam.cole@ontariotechu.net
Faculty Supervisor: Dr. Mika Nonoyama, mika.nonoyama@ontariotechu.net

If you have any questions about your rights as a participant in this study, complaints, or adverse events, please contact Ontario Tech University Research Ethics Office at (905) 7218668 ext. 3693 or at researchethics@uoit.ca.

If you have any questions concerning the research study, experience any discomfort related to the study, please contact Dr. Caroline Barakat at caroline.barakat@ontariotechu.ca.

Researchers have an interest in completing this study. Their interests should not influence your decision to participate in this study. For more detailed information related to the study or consent procedures, please refer to the complete consent form via https://forms.gle/STUSf9wUp8A5soTJA.

By agreeing to consent to this study you are agreeing with the following statements:

1. I am between 18-29 years of age
2. I have read the consent form and understand the study being described.
3. I have had an opportunity to ask questions if needed
4. I freely consent to participate in the research study, understanding that I may discontinue participation before I submit the survey without penalty

1. Do you reside in Canada? *
   Mark only one oval.

   - Yes
   - No (submission of form)
2. Are you between 18-29 years old? *

   Mark only one oval.

   - Yes
   - No (submission of form)

3. Do you agree to participate in this study? *
   Mark only one oval.

   - Yes
   - No (submission of form)

4. Can we use your data for secondary research purposes at a later date? Note that any secondary research will undergo a separate ethics review.
   Mark only one oval.

   - Yes
   - No

Section 5: Demographic Information

This section asks for your demographic data including your sex, gender identity, age, ethnicity, income, education, and postal code.

5. What sex were you assigned on your original birth certificate?
   Mark only one oval.

   - Female
   - Male

6. How would you describe your gender identity today?

   Mark only one oval.

   - Male
   - Female
   - Transgender
   - Do not identify as female, male, or transgender
   - Prefer not to say
   - Other:

7. How old are you today?

_____

8. Please choose the ethnic or cultural group that you come from or that best apply/applies to you
Check all that apply.

- ☐ White
- ☐ South Asian (e.g., East Indian, Pakistan, Sri Lankan, etc.)
- ☐ Chinese
- ☐ Black
- ☐ Filipino
- ☐ Latin American
- ☐ Arab
- ☐ Southeast Asian (e.g., Vietnamese, Cambodian, Laotian, Thai, etc.)
- ☐ West Asian (e.g., Iranian, Afghan, etc.)
- ☐ Korean
- ☐ Japanese
- ☐ First Nations (North American Indian), Métis or Inuk (Inuit)
- ☐ Prefer not to say
- ☐ Other:

9. What is the highest degree or level of school you have completed?

Mark only one oval.

- ◯ High school diploma or less
- ◯ College diploma or certificate
- ◯ Some university, or university certificate/diploma below the bachelor's level
- ◯ Bachelor's degree (e.g., BA, BSc, BASc)
- ◯ Master's degree (e.g., MA, MSc, MEng, Med, MBA)
- ◯ Professional school degree (e.g., MD, DDS, DVM, LLB)
- ◯ Doctoral degree (e.g., PhD, EdD)

10. What is your total annual personal income?

Mark only one oval.

- Less than $20,000
- $20,000 to less than $30,000
- $30,000 to less than $40,000
- $40,000 to less than $50,000
- $50,000 to less than $60,000
- $60,000 to less than $70,000
- $70,000 to less than $80,000
- $80,000 to less than $90,000
- $90,000 to less than $100,000
- More than $100,000
- I do not know
- Prefer not to say

11. What is/are your source(s) of income?

Check all that apply.

- ☐ Employment
- ☐ Government assistance
- ☐ Educational Assistance
- ☐ Assistance from family members/others/people I live with
- ☐ Other:_____

- My Parent(s)/guardian(s) *Skip to question 12*
- My partner/spouse *Skip to question 12*
- Roommate(s) *Skip to question 12*
- Family/Children *Skip to question 12*
- I live alone *Skip to question 13*
- Prefer not to say *Skip to question 13*
- Other:_____ *Skip to question 12*

12. What is your current living situation? (I live with...) (*Mark only one oval*)

Demographic Information

13. What is the combined annual income of your household?
Mark only one oval.

- Less than $20,000
- $20,000 to less than $30,000
- $30,000 to less than $40,000
- $40,000 to less than $50,000
- $50,000 to less than $60,000
- $60,000 to less than $70,000
- $70,000 to less than $80,000
- $80,000 to less than $90,000
- $90,000 to less than $100,000
- More than $100,000
- I do not know
- Prefer not to say

14. Please enter the first three digits of your current postal code (Example: L1V)

_____

Cannabis Consumption
The following questions ask about smoking and vaping cannabis.

Although other names for cannabis include marijuana, pot, weed, hash, and kush, we will be using the term cannabis consistently to refer to any of these products, and their different forms which include dried herb, oils or vape juice, hash/hashish, and concentrates (wax, shatter, budder, etc.).

Unless the question specifically relates to a specific form of cannabis, please include ANY of these forms when we ask you about cannabis. You will be asked about specific forms later in the survey.

'Smoking' cannabis refers to using any of the following methods: Spliff (mixture of tobacco and cannabis), Joint, Blunt (cigar sized joints), Bong, Hookah, or Pipe.

Blunt

Spliff/Joint

Hookah

Bong

Pipe

15. In the LAST 12 months, did you smoke cannabis?
    Please note that this section specifically asks about smoking cannabis. You will be asked about vaping later on in the survey.

    Mark only one oval.

    - ◯ Yes
    - ◯ No *Skip to question 21*

Cannabis Consumption

The following questions ask about how frequently you smoke cannabis and the method(s) you use to smoke cannabis.

16. How old were you when you FIRST started smoking cannabis?

    Mark only one oval.

- 15 or younger
- 16-17
- 18-19
- 20-21
- 22-23
- 24-25
- 26-27
- 28-29

17. How many days in your lifetime have you smoked cannabis?

Mark only one oval.

- 1-2
- 3-10
- 11-99
- 100-999
- More than 1000

18. When was the LAST time you smoked cannabis?

Mark only one oval.

- More than 3 months ago but less than 12 months ago
- More than 30 days ago but less than 3 months ago
- Within the past 30 days

19. Which of the following methods do/did you use 'regularly' when smoking cannabis? Please note that by 'regularly', we are referring to the method(s) that you use at least 25% of the time or more. [Select all that apply]

Check all that apply.

- [ ] Joint
- [ ] Spliff
- [ ] Blunt
- [ ] Hand pipe
- [ ] Bong
- [ ] Hookah

Other: [ ] _____

20. What is the 'primary' method you use to smoke cannabis? [Please note that by 'primary', we are referring to the method that you use predominantly, or most often]

Mark only one oval.

- ( ) Joint
- ( ) Spliff
- ( ) Blunt
- ( ) Hand pipe
- ( ) Bong
- ( ) Hookah
- ( ) Other:

Cannabis Consumption

In relation to smoking cannabis we recognize that there may be specific events that may have influenced or altered your consumption, such as legalization, the outbreak of the e-cigarette or vaping product use associated lung injury or 'EVALI', or the Corona-virus (COVID-19) pandemic.

The following questions ask about your frequency of smoking cannabis before and after these events:

In order to provide more context, legalization of recreational cannabis use occurred on October, 2018, in Canada.

In November, 2019, the Centers for Disease Control and Prevention (CDC) declared an “outbreak” of the e-cigarette or vaping product use associated lung injury also known as 'EVALI'.

In March, 2020, the World Health Organization (WHO) declared the corona-virus (COVID-19) as a pandemic. To date, hundreds of thousands of individuals have been infected with more than 70,000 deaths globally. As a result, many countries including Canada imposed physical distancing rules and diverse preventative measures.

21. How frequently do/did you smoke cannabis? (Mark only one oval per row)

	I did not smoke	Less than once a month	Once a month	2-3 times a month	once a week	Twice a week	3-4 times a week	5-6 times a week	once a day	More than once a day	Don't know
Prior to Legalization (approximately October, 2018)											
Since Legalization											
Prior to EVALI (approximately November, 2019)											
Since EVALI											
Prior to imposed COVID-19 preventative measures (approximately March, 2020)											
Since imposed COVID-19 preventative measures											

Vaping Cannabis

'Vaping' cannabis refers to using any of the following devices: Electronic Cigarette, Tabletop Vaporizer, Vape pen, Dab Pen, Dab Rig.

Tabletop Vaporizer

Electronic Vaping Devices

Dab Rig

22. In the LAST 12 months, have you vaped cannabis?

Mark only one oval.

- Yes
- No *Skip to question 28.*

Vaping Cannabis

The following questions ask about how frequently you vape cannabis and the methods you use to vape cannabis.

23. How old were you when you FIRST started vaping cannabis?

Mark only one oval.

- 15 or younger
- 16-17
- 18-19
- 20-21
- 22-23
- 24-25
- 26-27
- 28-29

24. How many days in your lifetime have you vaped cannabis?

Mark only one oval.

- 1-2
- 3-10
- 11-99
- 100-999
- More than 1000

25. When was the LAST time you vaped cannabis?

Mark only one oval.

- More than 3 months ago but less than 12 months ago
- More than 30 days ago, but less than 3 months ago
- Within the past 30 days

26. Which of the following methods do/did you use 'regularly' when vaping cannabis? Please note that by 'regularly', we are referring to the method(s) that you use at least 25% of the time or more. [Select all that apply]

Check all that apply.

- [ ] Electronic Cigarette
- [ ] Vape Pen
- [ ] Tabletop Vaporizer
- [ ] Dab Pen
- [ ] Dab Rig

Other: [ ] _____

27. What is the 'primary' method you use to vape cannabis. [Please note that by 'primary', we are referring to the method that you use predominantly, or most often]

Mark only one oval.

- Electronic Cigarette
- Vape Pen
- Tabletop Vaporizer
- Portable Vaporizer
- Dab Pen

- Dab Rig
- Other:

Cannabis Consumption

In relation to vaping cannabis we recognize that there may be specific events that may have influenced or altered your consumption, such as legalization, the outbreak of the e-cigarette or vaping product use associated lung injury or 'EVALI', or the Corona-virus (COVID-19) pandemic.

The following questions ask about the frequency of vaping cannabis consumption before and after these events:

In order to provide more context, legalization of recreational cannabis use occurred on October, 2018, in Canada.

In November, 2019, the Centers for Disease Control and Prevention (CDC) declared an "outbreak" of the e-cigarette or vaping product use associated lung injury also known as 'EVALI'

In March, 2020, the World Health Organization (WHO) declared the corona-virus (COVID-19) as a pandemic. To date, hundreds of thousands of individuals have been infected with more than 70,000 deaths globally. As a result, many countries including Canada imposed physical distancing rules and diverse preventative measures.

28. How frequently do/did you vape cannabis? (Mark only one box/oval per row)

	I did not vape	Less than once a month	Once a month	2-3 times a month	once a week	Twice a week	3-4 times a week	5-6 times a week	once a day	More than once a day	Don't know
Prior to Legalization (approximately October, 2018)											
Since Legalization											
Prior to EVALI											

(approximately November, 2019)											
Since EVALI											
Prior to imposed COVID-19 preventative measures (approximately March, 2020)											
Since imposed COVID-19 preventative measures											

Forms of Cannabis:

The following question asks about the forms of cannabis you smoke and/or vape REGULARLY.

Forms of cannabis include dried herb, oils or vape juice, hash/hashish, and concentrates (wax, shatter, budder, etc.).

'Regularly' refers to the forms of cannabis you use at least 25% of the time or more, when smoking and/or vaping.

29. What form(s) of cannabis do you use 'regularly'?

Check all that apply.

- ☐ Dried Herb
- ☐ Hash/Hashish
- ☐ Concentrates (e.g., Wax, Shatter, Butter etc.)
- ☐ Cannabis oil/vape juice (THC/CBD Oil)

Forms of Cannabis:

The following questions ask about the PRIMARY form of cannabis you smoke and/or vape.

‘Primary’ refers to the form that you use predominantly or most often.

30. Do you consider dried herb as one ‘primary’ form of cannabis that you use?

Mark only one oval.

Yes

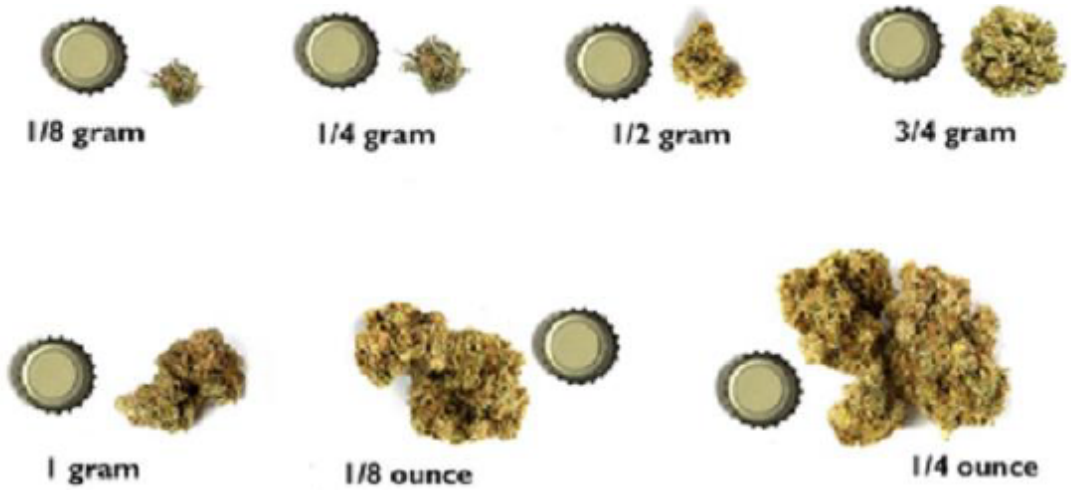
No *Skip to question 34*

Cannabis Plant:

The following questions ask you about how much, dried herb cannabis you use, personally (in joint size or grams).

Please see the images below for reference.

Amount of dried Herb (Note: 1/8 of a gram = 0.125 grams, ¼ of a gram = 0.25 grams, ½ of a gram = 0.5 grams, ¾ of a gram = 0.75 grams. 1/8 of an ounce = 3.5 grams, ¼ of an ounce = 7 grams, ½ ounce = 14 grams, 1 ounce = 28 grams) Do NOT include other forms of cannabis you may use.



Joint Size

31. Is it easier for you to tell us the joint size or the amount of dried herb (e.g., grams or ounces) you use(d)?

Mark only one oval.

- ◯ Joint Size
- ◯ Dried Herb *Skip to question 33*

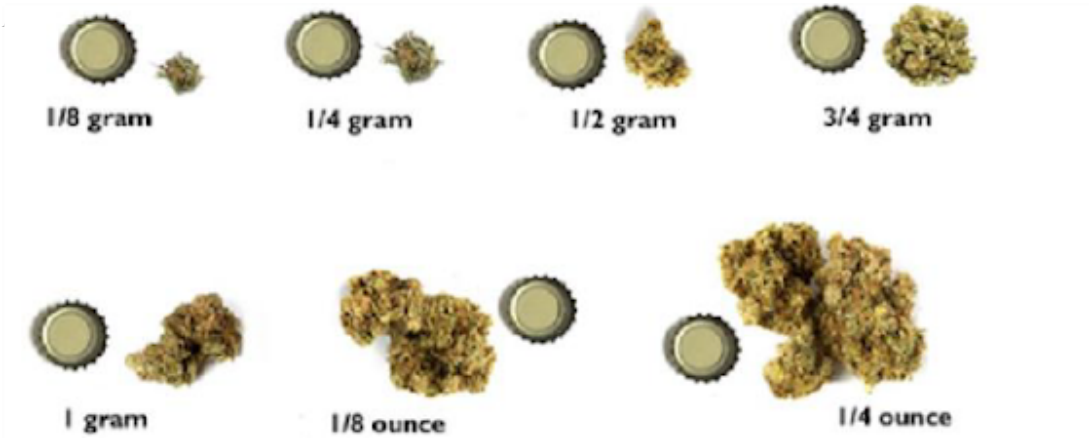
32. On the days you use(d) joints, what joint size is closest to the size you normally smoke(d)? (Mark only one box/oval per row).

	None	0.2 grams	0.4 gram	0.6 gram	0.8 gram	1.0 gram	1.2 gram	Don't know
Prior to Legalization (approximately October, 2018)								
Since Legalization								
Prior to EVALI (approximately November, 2019)								
Since EVALI								
Prior to imposed COVID-19 preventative measures (approximately March, 2020)								
Since imposed COVID-19 preventative measures								

33. On the days you use(d) joint(s), how many do/did you smoke?

	None	¼ joint	½ joint	¾ joint	1 joint	2 joints	3 joints	4 joints	5 joints	6 joints	7 joints	8 joints	9 joints	10 joints	More than 10 joints	Don't know
Prior to Legalization (approxi																

mately October, 2018)																
Since Legalization																
Prior to EVALI (approximately November, 2019)																
Since EVALI																
Prior to imposed COVID-19 preventative measures (approximately March, 2020)																
Since imposed COVID-19 preventative measures																



34. On the days you use(d) dried herb, about how much do/did you personally use?

(Mark only one box/oval per row).

	None	Less than 1/8 gram	1/8 (0.125) gram	1/4 (0.25) gram	1/2 (0.5) gram	3/4 (0.75) gram	1 gram	2 grams	3 grams	1/8 ounce	1/4 ounce	More than 1/4 ounce	Don't know
Prior to Legalization (approximately October, 2018)													
Since Legalization													

Prior to EVALI (approximately November, 2019)													
Since EVALI													
Prior to imposed COVID-19 preventative measures (approximately March, 2020)													
Since imposed COVID-19 preventative measures													

35. Do you consider Hash/Hashish as one 'primary' form of cannabis that you use?

Mark only one oval.

- Yes
- No *Skip to question 36*

Hash/Hashish
The following questions ask about how much hash/hashish you personally use (in grams).

The image below is provided for reference.

36. On the days you use Hash/Hashish how much did/do you personally use?
(Mark only one box/oval per row).

	None	Less than 1/2 (0.5) gram	1/2 (0.5) gram	1 gram	2 grams	3 grams	4 grams	5 grams	6 grams	7 grams	More than 7 grams	Don't know
Prior to Legalization (approximately October, 2018)												
Since Legalization												
Prior to EVAL I (approximately November, 2019)												
Since EVAL I												
Prior to imposed COVID-19 preventative measures (approximately March, 2020)												

Since imposed COVID-19 preventative measures												

Cannabis Concentrates

37. Do you consider cannabis concentrates (e.g., Wax, Shatter, Butane Hash Oil, Hash, Dabs) as one 'primary' form of cannabis that you use?

Mark only one oval.

- Yes
- No *Skip to question 38*

Cannabis Concentrates

This section asks about how much cannabis you use in concentrate form (in grams).

Cannabis Concentrates

38. On the days you use(d) concentrates approximately how much did/do you personally use?

	None	Less than 1/2 (0.5) gram	1/2 (0.5) gram	1 gram	2 grams	3 grams	4 grams	5 grams	6 grams	7 grams	More than 7 grams	Don't know
Prior to Legalization (approximately October, 2018)												
Since Legalization												
Prior to EVAL I (approximately November, 2019)												
Since EVAL I												
Prior to imposed COVID-19 preventative measures (approximately March, 2020)												

Since imposed COVID-19 preventative measures												

Cannabis Oil/Vape Juice

39. Do you consider cannabis oil/vape juice (THC/CBD Oil) as one 'primary' form of cannabis that you use?

Mark only one oval.

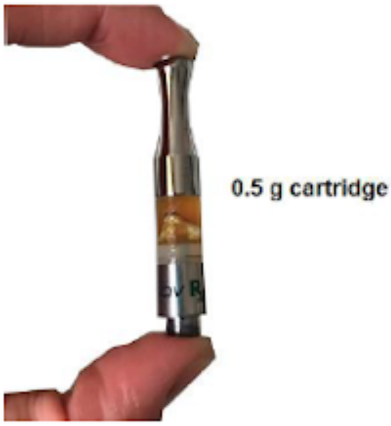
- Yes
- No *Skip to question 41*

Cannabis Oil/Vape juice

This section asks about your consumption of vaping cannabis oils/vape juice.

40. What size vaping cartridge do you 'primarily' use? [Please note that 'primarily' refers to the form you that you use predominantly or most often].

Note: cartridges come in sizes such as: 0.5 grams (500 mg); 1 gram (1,000 mg) OR 0.3 mL; 0.5 mL; 1mL. Please indicate the cartridge size in grams or mL. Please state if you 'do not know'. The image below is provided for reference.



_____

41. How many vape cartridge(s) or refill(s) did/do you use in a usual month?

	None	Less than half of a cartridge	1/2 of a cartridge	1 cartridge	2 cartridges	3 cartridges	4 cartridges	5 cartridges	6 cartridges	7 cartridges	8 cartridges	9 cartridges	10 cartridges	More than 10	Don't know
Prior to Legalization (approximately October, 2018)															
Since Legalization															
Prior to EVALI (approximately November, 2019)															
Since EVALI															

Prior to imposed COVID-19 preventative measures (approximately March, 2020)															
Since imposed COVID-19 preventative measures															

General Cannabis Use and Medicinal Cannabis Use

42. On the days you smoke and/or vape cannabis, how many hours a day do you usually spend high?

Mark only one oval.

- I do not get high when I use cannabis
- less than 1 hour per day
- 2 to 3 hours per day
- 4 to 5 hours per day
- 6 to 7 hours per day
- 8 to 9 hours per day
- 10 or more hours per day

43. On the days you smoke and/or vape cannabis, how soon after waking up do you take your first puff/drag? [only check the boxes that apply]

Check all that apply.

	When I vape cannabis	When I smoke cannabis
Immediately after waking up	☐	☐
Within the first 30 minutes	☐	☐
Within the first hour (60 minutes)	☐	☐
1-3 hours after waking up	☐	☐
3 or more hours after waking up	☐	☐

44. Do you consider yourself to be addicted to cannabis?
Mark only one oval.

- Not at all addicted
- A little addicted
- Very addicted
- I do not know
- Prefer not to say

45. How comfortable or uncomfortable do/would you feel openly using cannabis in public?

Mark only one oval.

	1	2	3	4	5	
Very uncomfortable	◯	◯	◯	◯	◯	Very comfortable

46. How many of your 5 closest friends use cannabis?

Mark only one oval.

- ◯ None
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 5or more

47. How harmful do you think it is to smoke cannabis?

	1	2	3	4	5	
Not at all harmful	◯	◯	◯	◯	◯	Very harmful

48. How harmful do you think it is to vape cannabis?

	1	2	3	4	5	
Not at all harmful	◯	◯	◯	◯	◯	Very harmful

49. Do you use cannabis for medicinal purposes?

Mark only one oval.

- Yes
- No *Skip to question 50*
- Prefer not to say *Skip to question 50*

Medicinal Cannabis Use.

The following section asks about the medical conditions you are prescribed cannabis for.

50. Which medical condition(s) do you use cannabis for?

_____

Tobacco Use.

The following questions ask about tobacco consumption.
By smoking tobacco, we are referring to using but not limited to any of the following methods: cigarettes, cigars, water pipe, etc.

51. Have you EVER smoked tobacco?

Mark only one oval.

- Yes *Skip to question 51*
- No *Skip to question 53*

52. Have you smoked tobacco 100 or more times in your lifetime?

Mark only one oval.

- Yes
- No

53. In the LAST 30 DAYS, did you smoke tobacco?

Mark only one oval.

- Yes
- No

Nicotine Use

The following questions ask about vaping nicotine.

54. Have you EVER used a vaping device with nicotine?

Mark only one oval.

- Yes *Skip to question 54*
- No *Skip to question 55*

55. In the LAST 30 DAYS did you use a vaping device with nicotine?

Mark only one oval.

- Yes
- No

56. Have you EVER mixed nicotine oil or nicotine vape juice/e-liquid products with THC or CBD oil when vaping?

Mark only one oval.

- Yes *Skip to question 56*
- No *Skip to question 57*

57. In the LAST 30 DAYS have you mixed nicotine oil or nicotine vape juice/e-liquid products with THC or CBD oil when vaping?

Mark only one oval.

- Yes
- No

Legalization of Recreational Cannabis Use.
The following questions ask you if your cannabis smoking and/or vaping consumption has been influenced or changed since recreational cannabis use was legalized in Canada, in October, 2018.

58. Has legalization changed your cannabis use?

Mark only one oval.

- Yes
- No *Skip to question 59*
- I do not know *Skip to question 59*

59. Please describe how legalization has changed your cannabis use:

_____

Cannabis Consumption

The following questions asks about your knowledge regarding EVALI ("e-cigarette or vaping product use associated lung injury") and if your cannabis smoking and/or vaping consumption has been influenced or changed because of this.

60. Prior to taking this survey, did you know about EVALI?
Mark only one oval.

- Yes
- No *Skip to question 62*

61. Has knowing about EVALI changed your cannabis use?

- Yes
- No *Skip to question 62*

62. Please describe how knowing about EVALI has changed your cannabis use:

_____

Cannabis Consumption

The following question asks about whether your cannabis consumption has been influenced or changed since the social and physical preventative measures put in place following the declaration of the COVID-19 pandemic in March, 2020.

63. Has the COVID-19 pandemic changed your cannabis use?

Mark only one oval.

- Yes
- No *Skip to question 64*
- I do not know *Skip to question 64*

64. Please describe how your cannabis use has changed since the COVID-19 pandemic:

_____

Cannabis Consumption

The following questions ask about your cannabis consumption since the social and physical preventative measures put in place following the declaration of the COVID-19 pandemic in March, 2020.

65. Since the preventative measures were put in place, have you used cannabis with other people?

Mark only one oval.

- Yes
- No
- Prefer not say

66. Since the preventative measures were put in place, how easy or difficult has it been for you to get cannabis?

Mark only one oval.

- Very easy
- Fairly easy
- Neither easy nor difficult
- Fairly difficult
- Very difficult
- I do not know

67. Are you aware that COVID-19 can harm the lungs?

Mark only one oval.

- Yes
- No

68. How susceptible do you think you are to serious illness related to COVID-19?

	1	2	3	4	5	
Not at all susceptible						Very susceptible

Respiratory Health

This section asks about your respiratory health and if you experience any respiratory symptoms.

69. In the LAST 30 DAYS, have you had any difficulty breathing?

Mark only one oval.

- Yes
- No

70. In the LAST 30 DAYS, have you been sick?

Mark only one oval.

- Yes
- No *Skip to question 72*
- I do not know *Skip to question 72*

71. Was your illness respiratory-related? (Ex: Cough, flu, cold, sore throat, runny nose)

Mark only one oval.

- Yes
- No
- I do not know

72. Was your illness related to COVID-19?

Mark only one oval.

- Yes
- No
- I do not know
- Prefer not to say

73. Have you ever had Asthma?

Mark only one oval.

- Yes
- No

74. In the LAST 12 MONTHS, have you coughed up phlegm in the morning?

Mark only one oval.

- Yes
- No

75. In the LAST 12 MONTHS, have you ever had wheezing or whistling in the chest?

Mark only one oval.

- Yes
- No

76. In the LAST 12 MONTHS, has your chest sounded wheezy during or after exercise?

Mark only one oval.

- Yes
- No

77. In the LAST 12 MONTHS, have you ever had a dry cough at night, apart from a cough associated with a chest infection?

Mark only one oval.

- Yes
- No

78. Were any of your respiratory symptoms (cough, wheeze, shortness of breath, chest tightness, sore throat) related to COVID-19?

Mark only one oval.

- Yes
- No
- I have not experienced any respiratory symptoms in the last 12 months
- I do not know
- Prefer not to say

Section: Contact Information

This section asks for your personal contact information if you wish to be contacted in the future for follow-up purposes and for the second phase of this study.

If you would like to be contacted again for further research please leave your information below

79. Please state your email address (Example: JohnDoe@hotmail.com)

_____

Thank you for completing the Survey!

Dear Participant,

Thank you for contributing your valuable opinion to this research study. Please find below some links to resources abut EVALI and COVID-19.

During this time, it is important to stay indoors and practice social distancing.

The following link gives you ideas about how to stay occupied during the pandemic.
https://www.vicnews.com/trending-now/40-things-to-at-home-during-thecoronavirus-pandemic/
If you would like to know more about COVID-19 please visit this link:
https://www.publichealthontario.ca/en/diseases-and-conditions/infectiousdiseases/respiratory-diseases/novel-coronavirus
If you would like to know more about EVALI, please visit this link:
https://www.canada.ca/en/public-health/services/diseases/vaping-pulmonaryillness.html
If you would like to know about resources that you can access for mental health purposes, please visit this link:
https://www.camh.ca/en/health-info/mental-health-and-covid-19

If you have any questions about our research, including learning about the aggregated results please contact Dr. Caroline Barakat (caroline.barakathaddad@uoit.ca).
Thank you again for your participation.
Sincerely,
Dr. Caroline Barakat
Ontario Tech University, Faculty of Health Sciences

Appendix C. Standard Student Recruitment Email

Target audience: Ontario Tech University Students

Subject line: Optional Research Study: Cannabis Consumption Profiles of Emerging Adults in Canada

Body:

This message is being sent on behalf of Dr. Caroline Barakat and Susan Yousufzai from the Faculty of Health Sciences. You are invited to participate in an **optional** research study on Cannabis Consumption Profiles of Emerging Adults in Canada. Participation is entirely **voluntary** and there is no obligation nor need to participate if you do not want to do so. For more information please direct any inquiries to Caroline.Barakat@ontariotechu.ca or susan.yousufzai@ontariotechu.net

If you are a young adult between **18-29 years old** who has smoked or vaped cannabis in the **last 12 months**, you are invited to participate in this research study being conducted to examine how profiles of cannabis consumption (route of consumption, form of cannabis, mode of use, frequency and quantity), may be influenced by specific events such as legalization, vaping associated lung injury outbreaks, and used in unprecedented times such as the current COVID-19 pandemic. Surveillance of perceptions and behavioral responses of individuals during pandemics provide useful information for health risk communication.

Participation in this research study will include an online survey that will take you approximately 20-25 minutes to complete. Please view the consent form which includes the names and information for the researchers, the purpose of the research, confidentiality, conflicts of interest, etc.

If you are interested in participating in this study, please visit the following link: survey to submit your responses. Please feel free to forward and share this link and information with your contacts.

If you have any questions regarding your rights as a participant or have any concerns about this study, please contact the Research Ethics Office at researchethics@uoit.ca or 905.721.8668 x3693.

This study has been reviewed by the Ontario Tech University Research Ethics Board [REB #15880] on May 4th, 2020.

Sincerely,

Dr. Caroline Barakat and Susan Yousufzai

Appendix D. Social Media Post (Facebook/Twitter)

Hi There!

We are a research group at Ontario Tech University, and we are recruiting for a study titled 'Cannabis Consumption Profiles of Emerging Adults in Canada'. If you are a young adult between **18-29 years old** who has smoked or vaped cannabis in the **last 12 months**, you are invited to participate in this research study being conducted to examine how routes of cannabis consumption (smoking and/or vaping) and exposure profiles (form of cannabis, mode of use, frequency and quantity), may change and be used in unprecedented times, such as the current COVID-19 pandemic.

Participation in this research study will include an online survey that will take approximately 20-25 minutes of your time. Please view the consent form which includes the names and information for the researchers, the purpose of the research, confidentiality, conflicts of interest, etc.

If you are interested in participating in this study, please complete this survey. Please feel free to forward and share this link and information with your contacts.

This study has been reviewed by the Ontario Tech University Research Ethics Board [REB #15880] on May 4th, 2020.

Sincerely,

Dr. Caroline Barakat

Faculty of Health Science, Ontario Tech University.

Appendix E. Survey Questions Guided by the Life Course Health Development Framework

Components of framework	Variables	Questions
Health Macro contexts	Culture and Policy Environment	Has legalization changed your cannabis use?
		Prior to taking this survey, did you know about EVALI?
		Has knowing about EVALI changed your cannabis use?
		Has the COVID-19 pandemic changed your cannabis use?
	Demographics	How old are you today?
		What sex were you assigned on your original birth certificate?
		Please choose the ethnic or cultural group that you come from or that best apply/applies to you
		What is the combined annual income of your household?
		What is your total annual personal income?
		What is the highest degree or level of school you have completed?
		What is your current living situation?
	Social environment	How comfortable or uncomfortable do/would you feel openly using cannabis in public?
		Since the preventative measures were put in place, how easy or difficult has it been for you to get cannabis?
		Since the preventative measures were put in place, have you used cannabis with other people?
		How many of your 5 closest friends use cannabis?
Health Micro contexts	Physiological pathways and systems	Have you ever had Asthma?
	Behavioural pathways and systems	In the LAST 12 months, did you smoke cannabis?
		In the LAST 12 months, did you vape cannabis?
		What is the 'primary' method you use to vape cannabis?
		What is the 'primary' method you use to smoke cannabis?
		How frequently do/did you vape cannabis (since COVID-19)?
		How frequently do/did you smoke cannabis (since COVID-19)?
		Do you consider dried herb as one ‘primary’ form of cannabis that you use?
		On the days you use(d) dried herb, about how much do/did you personally use (since COVID-19)?
		On the days you use(d) joints, what joint size is closest to the size you normally smoke(d) (since COVID-19)?
		On the days you use(d) joint(s), how many do/did you smoke (since COVID-19)?
		Do you consider Hash/Hashish as one 'primary' form of cannabis that you use?
		On the days you use Hash/Hashish how much did/do you personally use (since COVID-19)?
		Do you consider cannabis concentrates (e.g., Wax, Shatter, Butane Hash Oil, Hash, Dabs) as one 'primary' form of cannabis that you use?
		On the days you use(d) concentrates approximately how much did/do you personally use (since COVID-19)?
		Do you consider cannabis oil/vape juice (THC/CBD Oil) as one 'primary' form of cannabis that you use?
		How many vape cartridge(s) or refill(s) did/do you use in a usual month (since COVID-19)?

		In the LAST 30 DAYS, did you smoke tobacco?
		Have you smoked tobacco 100 or more times in your lifetime?
Mechanisms and Regulatory Processes	Onset of exposure to cannabis	How old were you when you FIRST started smoking cannabis?
		How old were you when you FIRST started vaping cannabis?
		How many days in your lifetime have you smoked cannabis?
		How many days in your lifetime have you vaped cannabis?
Health Outcomes	Respiratory Health	In the LAST 12 MONTHS, have you coughed up phlegm in the morning?
		In the LAST 12 MONTHS, have you ever had wheezing or whistling in the chest?
		In the LAST 12 MONTHS, has your chest sounded wheezy during or after exercise?
		In the LAST 12 MONTHS, have you ever had a dry cough at night, apart from a cough associated with a chest infection?