MARIJUANA BASELINE HEALTH STUDY

FINAL REPORT | JULY 2019

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OF PUBLIC HEALTH
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Suggested Citation:

Massachusetts Department of Public Health (2019). *Marijuana Baseline Health Study*. Retrieved from https://www.mass.gov/report/massachusetts-department-of-public-health-marijuana-research

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Executive Summary

A legislative mandate required the Massachusetts Department of Public Health (DPH) to conduct a baseline study to investigate three topics: (1) Patterns of use, methods of consumption, and general perceptions of marijuana; (2) Incidents of impaired driving and hospitalization related to marijuana use; and (3) Economic and fiscal impacts for state and local governments. Pursuant to Section 18 of Chapter 351 of the Acts of 2016, a Report of Findings was submitted to the legislature on June 29, 2018. This document serves as the Final Report.

Summary of Findings

(1) Patterns of Use and Perceptions of Marijuana

- A survey of adults in Massachusetts suggests that approximately 21% of adults have used marijuana in the past 30 days. The proportion of marijuana use was highest among those 18-25 years old. Smoking is the most common method of marijuana consumption, although more than 40% of marijuana users report using multiple methods of use. More than half of adults perceive marijuana to have slight or no risks, and use marijuana for non-medical purposes.

- A survey of patients who use marijuana products for therapeutic use suggests these individuals use marijuana treatments for approximately 24 days a month, with the majority of respondents using a marijuana product for at least 21 out of the past 30 days. On average, respondents spend at least $246.00 on marijuana each month, and use at least 3 different modes of use. The most common method of marijuana administration is smoking (combusting) dried flower (65%), followed by vaporizing marijuana concentrate (62%) and eating marijuana products (51%).

(2) Incidents of Impaired Driving and Hospitalization

- Tools to reliably ascertain levels of marijuana exposure and impairment in the field do not currently exist. Marijuana has cognitive and behavior effects in the areas of automative behavior (i.e., well-learned skills), and executive function impacts (i.e., how the user interacts with traffic). These effects have not been reliably linked to a level of marijuana or THC in the body.

- In a survey of Massachusetts residents, among respondents that use marijuana, the prevalence of self-reported driving under the influence is 34.3%. Overall, 7.2% of the adult population drove under the influence of marijuana in the past 30 days, and 11.3% of adults rode with a marijuana-using driver in the past 30 days. This is similar to estimates from a survey of medical marijuana patients that found approximately 10% of respondents drove under the influence in the past 30 days.

- Retrospective evaluations of fatal crash data suggest that drivers who died in a fatal crash are much more likely to have had their blood tested for marijuana, than drivers who survived a crash in which there was at least one fatality.
- Marijuana-related treatment is a small portion of the overall volume of substance use disorder treatment episodes. In a statewide-survey of Massachusetts, no respondents reported marijuana-related use of emergency room or urgent care facilities.

- The number of marijuana-related calls to the Regional Poison Control Center in Massachusetts has been increasing over time. The calls include incidents of unintentional exposures among children, with the majority of calls related to 10-19 year old individuals, and/or exposure to dried marijuana flower. The proportion of calls increased after medical marijuana was available in the Commonwealth.

(3) Economic and Fiscal Impacts for State and Local Governments

- Economic projections suggest that marijuana will increase Massachusetts state revenue by about $215.8 million in the first two years of retail sales. The increase will largely come from sales and excise taxes collected on retail purchases. Based on experiences from states with existing legalized adult use, sales tax revenue will be higher in the second year ($154.2 million), as compared to the first year ($61.6 million).

- Economic projections of the impacts to local government, suggest that local tax revenue over the first two years of retail sale are projected to be highest in the most densely populated regions (ranging from $233,498 to $2,875,048), with considerable fluctuation in two-year revenue projections among high-density suburban cities and towns (ranging from $68,139 to $991,873, over the two year period).

Acknowledgements

The MBHS was directed by DPH in consultation with an advisory panel consisting of representatives from the Executive Office of Health and Human Services, Executive Office for Administration and Finance, and the Executive Office of Public Safety and Security. The study was funded by the Medical Use of Marijuana Trust Fund.

The completion of this study would not have been possible without the assistance of study collaborators from the University of Massachusetts (UMass); Mathematica Policy Research (Mathematica); and JSI Research and Training Institute, Inc. (JSI).

Specific collaborators on the “Retrospective Analysis of Indicators of Use and Perceptions of Marijuana” include: Catherine Jett, Adama Brown-Hathaway, and Penny Brierley-Bowers of the University of Massachusetts Donahue Institute.

Specific collaborators on evaluating the “Prevalence and Correlates of Marijuana Use among Adults in Massachusetts” include: Elizabeth Evans, Jennifer Whitehill, Eva Goldwater, Ed Stanek III, Penny Brierley-Bowers, and David Buchanan of the School of Public Health and Health Sciences, University of Massachusetts Amherst.

Specific collaborators evaluating the “Use and Perceptions of Marijuana among Adult Medical Use of Marijuana Patients in Massachusetts” include: Thomas W. Mangione, Natalie Spitzer, Rebecca Millock, Mihaly Imre and Heather E. Lisinski of JSI Research & Training Institute, Inc.

Specific collaborators on “Measuring Marijuana Exposure and its Effects Related to Driving Impairment: A State of the Science Review” include: Jennifer M Whitehill and Tyler Jette of the School of Public Health and Health Sciences, University of Massachusetts Amherst

Specific collaborators on evaluating “Driving Under the Influence of Marijuana and Marijuana-involved Motor Vehicle Crashes in Massachusetts” include: Jennifer M. Whitehill, Cole Fitzpatrick, Eva Goldwater, Edward Stanek III, Elizabeth Evans, and David Buchanan of the School of Public Health and Health Sciences, University of Massachusetts Amherst.

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Specific collaborators on evaluating “Estimating Fiscal effects of Legalization in Massachusetts” include: Aparna Keshavia, Eric Morris, Dara Lee Luca, Sara Le Barron, Colleen Staatz, and David Jones of Mathematica Policy Research.

The protection of human participants in the research described in this report was ensured through review and approval by the Massachusetts Department of Public Health Institutional Review Board (IRB), and the Commissioner of Public Health pursuant to M.G.L. c.111, § 24A. For questions related to IRB or § 24A protections, please contact the Institutional Review Board at 617-624-5621 and reference the Marijuana Baseline Health Study, Principal Investigator Marc A. Nascarella, PhD, IRB# 1081301.

Introduction

A legislative mandate required the Massachusetts Department of Public Health (DPH) to conduct a baseline study to investigate three topics: (1) Patterns of use, methods of consumption, and general perceptions of marijuana; (2) Incidents of impaired driving and hospitalization related to marijuana use; and (3) Economic and fiscal impacts for state and local governments (Chapter 351 of the acts of 2016). This study, referred to as the Marijuana Baseline Health Study (MBHS), was conducted by DPH, under the leadership of the DPH Commissioner, in consultation with the Executive Office of Health and Human Services, the Executive Office for Administration and Finance, and the Executive Office of Public Safety and Security. Pursuant to the legislative mandate, DPH entered into an agreement with the following research entities to assist with the execution the study: University of Massachusetts Donahue Institute, Mathematica Policy Research Inc., and JSI Research and Training, Inc. Pursuant to Section 18 of Chapter 351 of the Acts of 2016, a Report of Findings was submitted to the legislature on June 29, 2018. This document serves as the Final Report

Topic 1: Patterns of Use and Perceptions of Marijuana

a. Retrospective Evaluation

A retrospective analysis of previous surveys of "marijuana use" was conducted by comparing national and state-specific information from three states which have legalized marijuana, compared to three states which have not. This evaluation was conducted to identify indicators which may be sensitive to factors associated with legalization of marijuana, thus providing a valuable reference to monitor trends in use and perceptions of marijuana as the legalization of marijuana progresses. This retrospective analysis suggests that thirteen different indicators from national surveys with information available at the state level appear to be responsive to factors associated with the legalization of marijuana and sensitive to changes over time. These indicators include evaluating if minors have "ever used marijuana," and if they "believe occasional use poses no risk of harm." The evaluation also suggests that monitoring similar indicators in adults is valuable, as well as monitoring indicators of "perceptions of great risk from smoking marijuana once a month" and "any use in the past year."

b. Statewide Survey

A cross-sectional population-based survey of adults was conducted to assess past 30-day use of marijuana, alcohol, and other substances. For each of these three substance types, the survey collected information on frequency of use, spending on the substance, driving under the influence, riding as a passenger with a driver under the influence, and use of emergency room or urgent care services. The mail and web-based survey was designed to be representative of adults in Massachusetts, age 18 years or older. Participants were chosen randomly using address-based sampling from a list of Massachusetts residential households obtained through a sampling vendor. The sample was stratified by 6 regions (Boston, Central, Metrowest, Northwest, Southeast, and

Western). A simple random sample of 15,000 addresses were selected to participate with an equal number of households (n = 2,500) selected from each region.

Once duplicates were removed from the study results, there were 3,022 individuals that responded to the survey (21.8% response rate). The respondent data was weighted to allow estimates to be representative of the entire Massachusetts population. These weighted results suggest that 21% of adults in Massachusetts have used marijuana in the past 30 days; 26% of men and 17.0% of women. The proportion of marijuana use was highest among those 18-20 years of age and 21-25 years (54.4% and 49.1%, respectively), as compared to older age groups. Eighteen percent of adults aged 26 or older had used marijuana in the past 30 days. By region, residents in the Western area of the state report the highest prevalence of past 30-day marijuana use (~30%). Among marijuana users living in Massachusetts, most are White, 70.8%, and many fewer are Hispanic, 12.0%, Black, 7.1%, other, 6.9%, or Asian, 3.2%. In statistical analysis of the data (which accounted for the effect of other factors), race/ethnicity was not associated with marijuana use, suggesting that the likelihood of using marijuana is similar for each group (compared to Whites). Fifty-three percent of adults perceive marijuana to have slight or no risks. The patterns of marijuana consumption indicate that smoking is most common, although 43% of marijuana users report using more than just one method. More than half of all adult marijuana users (56.0%) report using marijuana only for adult non-medical purposes. Data suggest that men are more likely than women to report past 30-day use, and adults 18-20 years old are more likely to have used marijuana, compared to adults older than 26 years old. Marijuana use is positively associated with past 30-day alcohol use. Population groups such as men, White, non-Hispanic individuals and individuals age 18-20 years had the highest prevalence of marijuana use, when compared to other groups.

c. Survey of Medical Use of Marijuana Patients

An online survey of the patterns of use and perceptions of marijuana was sent to patients actively using medical marijuana. The survey remained open for approximately 5 weeks, with a stated goal of characterizing how regulated legal retail marijuana is consumed in Massachusetts. The survey included 81 questions focused on collecting information on demographics, product use, methods of use, perceptions of medical use, driving behavior, alcohol consumption, non-medical use of prescription drugs and other substances, and combined substance use.

A total of 6,934 participants completed the entire survey, for a response rate of 16%. There were no notable differences between respondent gender, age, or county of residence as compared to the eligible population (i.e., all patients). On average, respondents indicated marijuana use for 23.5 out of the past 30 days, with over 60% reporting marijuana use at least 21 out of the past 30 days. However, 8% of respondents reported no use of marijuana or marijuana products in the past 30 days. Over 65% of respondents reported using marijuana or marijuana products for medical purposes for at least 1 year, with approximately 1 in 5 of respondents using marijuana or marijuana products for medical purposes for at least 3 years. On average, respondents reported spending $246 on marijuana products in the past 30 days, with a significantly larger amount spent among respondents under 50 years old and among respondents with an educational attainment less than a Bachelor's degree. On average, participants reported using approximately 3 different modes of use in the past 30 days. Approximately 16% of respondents who indicated marijuana use in the past 30 days reported using only 1 method of administration, while over 30% reported using 4 or more methods. The most common method of marijuana administration was smoking dried flower (65%), followed by vaporized marijuana concentrate (62%) and edible marijuana products (51%). The amount of product used varied by gender, age group, and educational attainment. A significantly larger proportion of males compared to females reported using vaporized dried flower or a concentrated preparation of THC referred to as "dabbing", while a larger proportion of females compared to males reported using sublingual or orally administered uptake products and applying topical cannabis products to the skin. A significantly larger proportion of respondents 50 years old or younger reported smoking (combusting) dried flower cigarettes (or "joints"), vaporizing dried flower, vaporizing marijuana concentrate, dabbing, or consuming edible marijuana products. A significantly larger proportion of respondents with an educational attainment less than a Bachelor's degree reported smoking dried flower and dabbing compared to respondents with a Bachelor's degree or higher.

All respondents were asked questions related to their perceptions of the medical use of marijuana. Over 65% of respondents reported that they believed marijuana products have been "very effective" in treating their medical condition(s), while an additional 26% believed use of marijuana to be "effective." Almost 90% of respondents reported that they had "somewhat high" or "very high" confidence that they were receiving safe, uncontaminated products when purchasing marijuana or marijuana products at a registered medical marijuana dispensary. All respondents were asked questions related to positive and negative outcomes/consequences of their marijuana use. Overall, respondents reported high rates of positive outcomes/consequences of marijuana use, and little obvious harm. Among all respondents, 78% reported positive changes in their mood or mental health, and 67% reported improved physical health. In addition, 83% of respondents reported no negative outcomes/consequences related to their marijuana use. Approximately 10% of respondents reported driving or operating a car or other motor vehicle while under the influence of marijuana in the past 30 days.

Topic 2: Incidents of Impaired Driving and Hospitalization

a. Measuring Marijuana and Driving Impairment

Marijuana intoxication can impair psychomotor and cognitive functions related to driving and increase the risk of involvement in a motor vehicle crash. A literature review was conducted to examine the state of the science on quantifying marijuana and impairment leading to the inability to operate a motor vehicle. Various point-of-collection (POC) devices/kits were compared to standard analytical chemistry methods (e.g., gas chromatography mass spectrometry, or liquid chromatography- tandem mass spectrometry) to determine concentrations of Δ9-tetrahydrocannabinol (THC), the primary psychoactive compound in marijuana. While some of the POC devices showed a screening-level accuracy that meets or exceeds recommended standards, they are limited in their ability to serve as a diagnostic tool to indicate driving impairment. The review of studies assessing cognitive and behavioral impacts of marijuana that are relevant to driving indicate that marijuana has cognitive and behavior effects in the areas of automative behavior (i.e. well-learned skills), especially for occasional users, and there also are likely executive function impacts (i.e. how the user interacts with traffic) for some users. Additional research is needed to establish baseline levels of cannabinoids in blood, urine, and saliva, and the relationship between these levels and marijuana use. Additional data are also needed to characterize the variability in cannabinoid levels across product types and modes of consumption.

b. Baseline Assessment of Medical Use of Marijuana Patients

As a follow-up to the survey of Medical Use of Marijuana patients described above, DPH conducted a biomonitoring study to evaluate baseline levels of tetrahydrocannabinol (THC) and 1-nor-9-carboxy-Δ9-tetrahydrocannnabinol (THC-COOH) in the blood and urine of patients that were regular marijuana consumers. This study, referred to as the Baseline Assessment of Medical Marijuana Patients (BAMMP) Study, was conducted in two distinct phases. The first "recruitment" phase, involved leveraging the patient survey component of the MBHS sent to 42,519 active medical marijuana patients, and included opinion, attitude, and perception questions as well as questions specifically addressing the magnitude, frequency, type and method of marijuana use. The survey also collected data on the social and demographic characteristics of respondents, including: age, gender, race/ethnicity, employment status, income level as well as county and zip code of residence. Recruitment of BAMMP study participants from the 6,934 patient survey respondents was achieved by creating a pool of respondents that indicated an interest in participating in a follow-up research study (e.g., question No. 81 on the patient survey; see Appendix B). From this pool of 2,113 interested individuals, 333 participants were selected for follow-up for study participation based on a sampling methodology to generate a sample representative of the geography, race/ethnicity, age, and gender of the statewide population. The second "field-based" phase of the BAMMP study involved the recruitment, scheduling, and collection of detailed marijuana use information and biological specimens (e.g., blood and urine) from 134 of the 333 individuals. These field-based appointments were conducted across the state of Massachusetts, where each of the 134 participants executed a consent form, returned a completed 7-day marijuana use diary, responded to questions on a same-day questionnaire, and underwent a physical and cognitive evaluation to confirm that they were not impaired. Participants then provided clinical specimens of either urine (n = 16), or urine and blood (n = 118) for quantitative analysis of THC and THC-COOH. A full report of the BAMMP study findings are expected later this year.

c. Marijuana-Involved Motor Vehicle Crashes in Massachusetts

Baseline prevalence of self-reported DUI-marijuana and riding with a driver under the influence of marijuana (RUI-marijuana) was characterized to identify demographic risk factors associated with these behaviors. Retrospective trends and patterns of marijuana-involved motor vehicle crashes in Massachusetts were investigated between 2006 and 2016, using (1) DUI and RUI data collected as part of a statewide baseline survey of Massachusetts adults age 18 years and older; (2) Prevalence of marijuana, alcohol and drug-involved fatal crashes in Massachusetts from 2006-2016; and (3) Marijuana-involved non-fatal crashes in Massachusetts. The baseline data in Massachusetts suggests that approximately 7% of adults drove under the influence of marijuana in the past 30 days and about 12% of adults rode with a driver who was under the influence of marijuana. Nearly 35% of adults who reported marijuana use also reported DUI-marijuana, and a similar proportion reported RUI-marijuana. Retrospective evaluation of fatal crash data suggest that over the 11-year study period of 2006-2016, there were an average of 351 crashes per year in which someone died and an average of 373 traffic fatalities per year. Approximately 73% of the drivers who died in a crash were administered a post-mortem blood test. Of the deceased, blood-tested drivers, there was an increasing trend for the proportion or drivers testing positive for any cannabinoid post-mortem. In contrast, alcohol-involved crashes in Massachusetts have steadily decreased in frequency since 2006. In an examination of non-fatal crash data, an increasing number and proportion of crash reports describe marijuana. These reports preclude the accurate characterization of marijuana-involved, non-fatal crashes as the crash reports do not systematically include reporting of drug testing.

d. Marijuana-Related Health System Contacts in Massachusetts

The use of health care systems by frequent and occasional marijuana users was evaluated to determine the number and prevalence of (1) substance use treatment admissions for a primary diagnosis of cannabis use disorder; (2) emergency room and urgent care services due to marijuana, and (3) marijuana-related calls received by the regional poison control center (PCC). This phase of the study sought to provide a summary of valuable health system-related indicators from before retail sales of adult use marijuana. For this phase, three data sources were utilized for analyses. First, Massachusetts-specific data were extracted from a national substance use database to compile the number of marijuana-related treatments over 2004-2014. Second, baseline data from the statewide survey on emergency or urgent care related to marijuana use, alcohol use, and other substance use were evaluated. Finally, data from the Massachusetts and Rhode Island Regional Poison Control Center (PCC) were evaluated to characterize marijuana-related calls (for all exposure reasons) by age and year, trends in specific marijuana product type as the source of exposure (e.g. dried plant, edible preparation, etc.).

These evaluations suggest that marijuana-related treatment is a small portion of the overall volume of substance use disorder treatment episodes, with an estimated prevalence of 45 admissions per 100,000 individuals. Of the 436 individuals who reported using marijuana in the past 30 days on the statewide-survey, no respondents reported marijuana-related use of emergency room or urgent care services in the prior year. Data from the PCC suggest that the number and proportion of marijuana-related calls has been increasing over time for all age groups. For example, during the 10-year study period (2007-2016) there were 641 calls to the PCC that involved marijuana exposure, equal to a prevalence of 9.4 calls per a 100,000 population. The evaluated calls include incidents of unintentional exposures among children age 0-9 years old (n = 27, 4.21%). The greatest number of calls were related to 10-19 year old individuals (n = 257, or 40.09%). The proportion of calls due to marijuana exposure in individual ages 0-5, 6-9, and 10-20 years old showed a statistically significant increase after medical marijuana was enacted in the Commonwealth. In all age groups, it was exposure to dried cannabis plant that resulted in the greatest number of calls to poison control, followed by edible preparations.

Topic 3: Economic and Fiscal Impacts for State and Local Governments

To evaluate the potential economic impacts on state and local government, a model was constructed to estimate the fiscal impacts during the first two years of retail sales. The model included three parts: (1) a main model, which included measures that were assumed to be major drivers of state economic impacts for which there is strong evidence to inform estimates (e.g., sales tax revenue, regulatory oversight costs and revenue, and reductions in marijuana-related law enforcement activities); (2) a supplemental model, which evaluated secondary impacts on public health, public safety, and income tax revenue for which the strength of the evidence is less definitive; and (3) a local model, which estimates local tax revenue for each city or town in Massachusetts (assuming the maximum local tax rate of 3%).

This approach suggests that marijuana will increase Massachusetts state revenue by about $215.8 million in the first two years of retail sales. The increase will largely come from sales and excise taxes collected on retail purchases. Based on experience from states with existing legalized adult use, sales tax revenue will be higher in the second year ($154.2 million), as compared to the first year ($61.6 million). When measures calculated with less certainty are included in the model (because of either a lack of data or uncertain timing), the state revenue may increase by an additional $65.3 million. Because the model includes multiple measures, the overall estimate compounds uncertainty from each of the measures. To address this, low and high ranges have been calculated. For example, the total fiscal contribution could range from $95.7 to $405.9 million, with two major assumptions heavily influencing the estimates. The first assumption involves the number of expected marijuana users in Massachusetts. While the model uses previous population surveys that show a prevalence of use ranging from 8.6% to 12.1%, data collected in Massachusetts suggest that it may be as high as 20.1%.When this Massachusetts-based estimate is used, revenue projections increased by 38% (from $215.8 million to $298.8 million). Another source of uncertainty is the changes that arise in a state when moving a regulated medical marijuana marketplace to a combined medical and adult-use marketplace, versus changes in a state going from no sales to adult-use retail sales.

The model-based approach of estimating fiscal impacts to local government, projects that local tax revenue over the first two years of retail sale are projected to be highest in the most densely populated regions (ranging from $233,498 to $2,875,048), with considerable fluctuation in the two-year revenue projections in high-density suburban cities and towns (ranging from $68,139 to $991,873, over the two year period). These local analyses assume that approximately 65% of marijuana users would shift from purchasing their marijuana in the illicit marketplace to purchasing from a dispensary. In general, the estimated median local tax revenue over the first two years of retail sale ranges from $72,835 in suburban communities with a low population density, to $582,899 in urban communities with a high population density. Because these model estimates rely on the location and availability of dispensaries, each community-level estimate is dependent upon the availability of marijuana in that community and the demand for marijuana in nearby communities. For some of the 83 cities and towns included in the primary analysis, local tax revenue estimates fluctuated dramatically based on these community-level effects (for example, from about $992,000 to $108,000).

In general, the modeling efforts described here estimate that adult-use marijuana sales are driven primarily by the availability of dispensaries and the potential for medical marijuana dispensaries to expand and/or convert operations to include adult-use marijuana sales. The increase in revenue will largely be a result of retail purchases made by adults with heavy use (defined as consuming marijuana an average of 21 days or more each month). It is difficult to speculate what regulatory costs/benefits may have already been realized when Massachusetts implemented a medical marijuana program. For example, if revenue changes have already been realized, the assumption could be inflating some of the revenue projections by 7-28%. While it is important to consider all aspects of the fiscal impact of legalization, the estimated increase from sales and business tax revenue appear to be most significant.

Task 1: Prevalence and Perceptions of Marijuana Use

Chapter 1: Retrospective Analysis of Indicators of Use and Perceptions of Marijuana

Introduction

In this chapter an exploratory, secondary data analysis of marijuana indicators using national and state-specific data from Massachusetts as well as three states which have fully legalized marijuana (Oregon, Washington, and Colorado) and three states which have made no changes to marijuana laws (Texas, Kansas, Oklahoma) is presented. The goal of the study was to identify indicators of use and perception of risk of marijuana that may be used by policymakers and program leaders to monitor the impact of the legalization of marijuana over time.

Background

During the past two decades, there have been many state policy changes with regard to marijuana use. Currently, 29 states and the District of Columbia have legalized medical marijuana and 8 states have legalized recreational marijuana. National data indicates that marijuana is the most commonly used illicit drug in the U.S. and the shifts in policy align with changes in public opinion regarding the acceptance and legality of marijuana. In addition, an increase in marijuana use prevalence and a decrease in the perceived harmfulness of marijuana use have also been noted (Hall & Kozlowski, 2015; Monte, Zane, & Heard, 2015). Recent polls show growing support for the legalization of marijuana, with some reports indicating that over 50% of Americans now view the use of marijuana as a non-moral issue (Swift, 2013; Pew Research Center, 2013). Between 2002 and 2014, marijuana use increased from 10.2% to 13.4% among adults, and the perception of harmfulness associated with marijuana use decreased from 40% to 27.8% (Swift, 2013).

Although trends in marijuana use for both adolescents and adults have been examined using national data as well as data specific to states that have legalized marijuana, few studies, if any, have conducted a comparative analyses of legalized states versus non-legalized states with regard to marijuana use (Swift, 2013; Pew Research Center, 2013; Allen & Holder, 2014; Keyes, et al. 2016). And while several studies have examined trends in marijuana use following its legalization in specific states, these trends have not been examined in relation to key policy milestones. The purpose of this study is to conduct a comparative, secondary data analysis of marijuana indicators using national and state-specific data from three legal states (Oregon, Washington, Washington) and three non-legal states (Texas, Kansas, Oklahoma). Recreational marijuana was legalized in Massachusetts in 2016, and a focal point of this study is to compare Massachusetts indicators to other states in order to identify indicators which are responsive to changes in legalization. Given changes in marijuana policies regarding recreational use, the primary purpose of this study is to identify indicators that may be sensitive to those changes and factors associated with marijuana. The data reported reflect marijuana indicators that were reported for both legal and non-legalized comparison states.

Methods

In order to identify the indicators which may be sensitive to factors associated with legalization of marijuana, a list of the most relevant potential indicators from four national data sets was detailed. This list was then honed to only those which met specific criteria for inclusion. The remaining indicators were then analyzed for responsiveness to factors associated with marijuana and change over time. In sum, the process included four steps:

1. Conduct an indicator inventory
2. Choose comparison states
3. Confirm data sources
4. Conduct statistical analyses

Along with identifying indicators that appear to be responsive to changes over time, this approach also provided a baseline for chosen indicators from which to assess future trends.

Indicator Inventory

The purpose of the inventory was to identify a comprehensive list of potential indicators and detail salient information to inform the selection of indicators for further analysis. Four data sets were selected from which to pull the comprehensive list of indicators:

- Massachusetts Youth Risk Behavior Survey (YRBS)
- Massachusetts Youth Health Survey (YHS)
- Massachusetts Behavioral Risk Factor Surveillance Survey (BRFSS)
- National Survey on Drug Use and Health (NSDUH*)*

Sixty-eight initial indicators were identified for consideration. From this list, indicators were chosen that met the following criteria:

- Represents population of youth and/or adults
- Availability in potential comparison states
- Sampling and weighting representative of the entire state
- Administration at regular intervals over the course of the last 10 years

The result of the prioritization was the identification of 22 indicators for further analysis.

Selection of Comparison States

The next step was to select comparison states. Two types of comparison states were selected: those that have legalized recreational marijuana and those that have not legalized nor decriminalized marijuana use. Many states have made some changes to marijuana laws either by decriminalizing, legalizing medical marijuana use, or ultimately legalizing recreational marijuana use. These changes appear to occur in a progression and therefore our focus was to identify states on either end of the continuum. The map below (Figure 1) demonstrates the range of legalization across the United States.

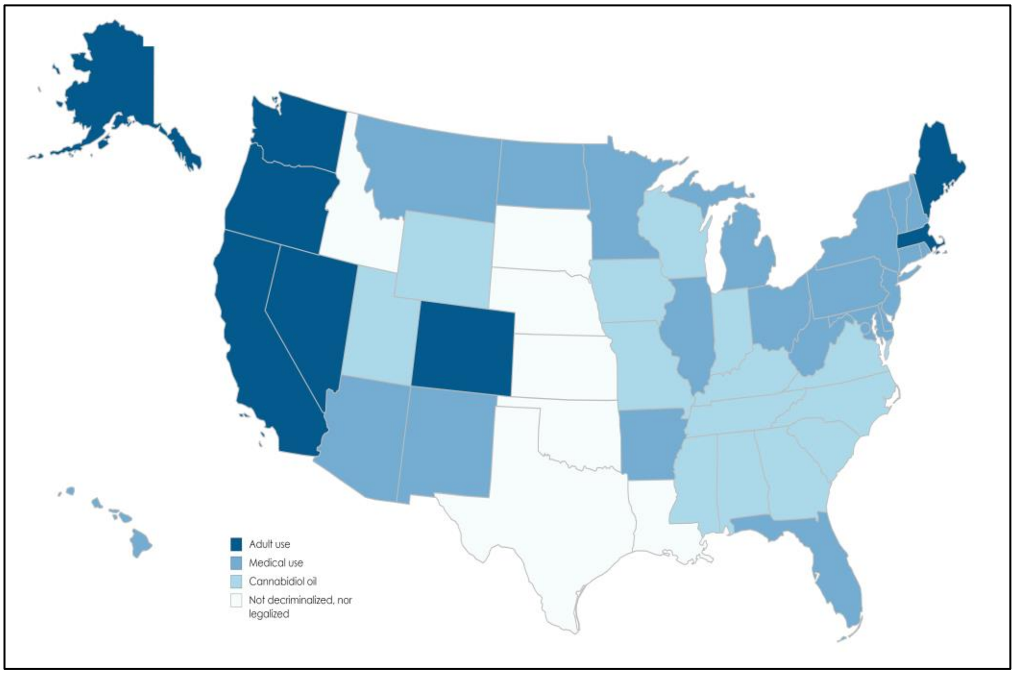


Figure 1: Current marijuana legalization status by state

For the purposes of this analysis, legalized comparison states considered included Washington, Oregon, California, Nevada, Colorado and Maine. However, only three states had legalized recreational use for sufficient time to make a trend analysis plausible: Washington, Oregon and Colorado.

A search found that there are seven states which have not decriminalized marijuana use or possession and have no recreational or medical marijuana laws, nor any legal cannabidiol oil use. These include: Idaho, Kansas, Louisiana, Nebraska, Oklahoma, South Dakota and Texas. It was assumed that states that meet this profile would be politically dissimilar (e.g. approach to criminal justice reform, social programs, etc.) from Massachusetts and therefore selecting on the basis on similarity of social factors would not be fruitful. Therefore, the selection criteria focused upon population density and unemployment rate. The table below details how each state met those criteria. Of the seven potential comparison states, the three selected had the most similar unemployment rate and population density to Massachusetts. Based on this information, the chosen non-legalization comparison states were Texas, Oklahoma and Kansas.

Table 1: Comparison State Census Information

State	Population	People per sq. mile	Unemployment rate
Massachusetts	*6,547,629*	*839.4*	*4.3%*
Idaho	1,567,582	19.0	3.1%
Kansas	2,853,118	34.9	3.7%
Nebraska	1,826,341	23.8	2.9%
Oklahoma	3,751,351	54.7	4.3%
South Dakota	814,180	10.7	3.0%
Texas	25,145,561	96.3	4.6%

Confirmation of Data Sources

Once the indicators and comparison states were chosen for analysis, the data sets were obtained. For adults, the final data sources include the NSDUH and the BRFSS. While raw NSDUH data were not available due to upgrades to SAMHSA's online data portal and restricted data access system, a limited number of NSDUH indicators (with point estimates and confidence intervals) were available from SAMHSA's public data access system for Massachusetts, the U.S., and all comparison states. BRFSS data regarding marijuana were only available for Washington state; other states did not include marijuana questions or included them too recently for a trend analysis to be conducted. For youth, the final data sources included the NSDUH, the YRBS, the YHS, the Healthy Youth Survey from Washington state. While the Healthy Kids Colorado Survey and the Oregon Healthy Teen Data Set were explored for use. Ultimately, they were not used due to their failing to meet the criteria set forth for the indicator inventory or their indicators did not align with Massachusetts indicators. The NSDUH data were available as described above through the public data access system for a limited number of indicators for youth aged 12-17. For high school youth, YRBS data were available for the U.S., Massachusetts, Texas, Kansas, and Oklahoma. Colorado deployed the YRBS through 2011, then switched to include the YRBS instrument in the Healthy Kids Colorado Survey, which is available for 2013 and 2015. In Washington State, the Healthy Youth Survey sampled students in grades 10 and 12; these data are not directly comparable to YRBS data but are presented on their own for trend analysis. The raw Healthy Youth Survey data were not available, but point estimates and confidence intervals available from published reports were used. For middle school youth, Massachusetts data are available from the YHS, and Washington state data are available from the Healthy Youth Survey for grades 6 and 8.

Statistical Analysis

Where raw data were available (for the YRBS, BRFSS, YHS), tests for linear and non-linear trends using logistic regression were conducted. Data were compiled and analyzed in two ways. Variables representing gender, race, and grade (in the case of youth data) were entered as control variables to adjust for demographic shifts in the underlying populations. Where raw data were not available, a significant trend was determined by non-overlapping confidence intervals; this analysis did not adjust for demographic variables. Because the sampling for each of the surveys involved complex sampling, SPSS Complex Samples version 21.0 was used to account for the sampling design and to ensure there was not an underestimation of the standard errors (Cambron, Guttmannova & Fleming, 2017).

Finally, a literature review of peer-reviewed journal articles related to marijuana legalization and block grant review was conducted to inform the selection of key milestones related to marijuana legislation in each state. Trends for each of the marijuana indicators were plotted alongside the key milestones to illustrate which indicators may be sensitive to state-level changes.

Results

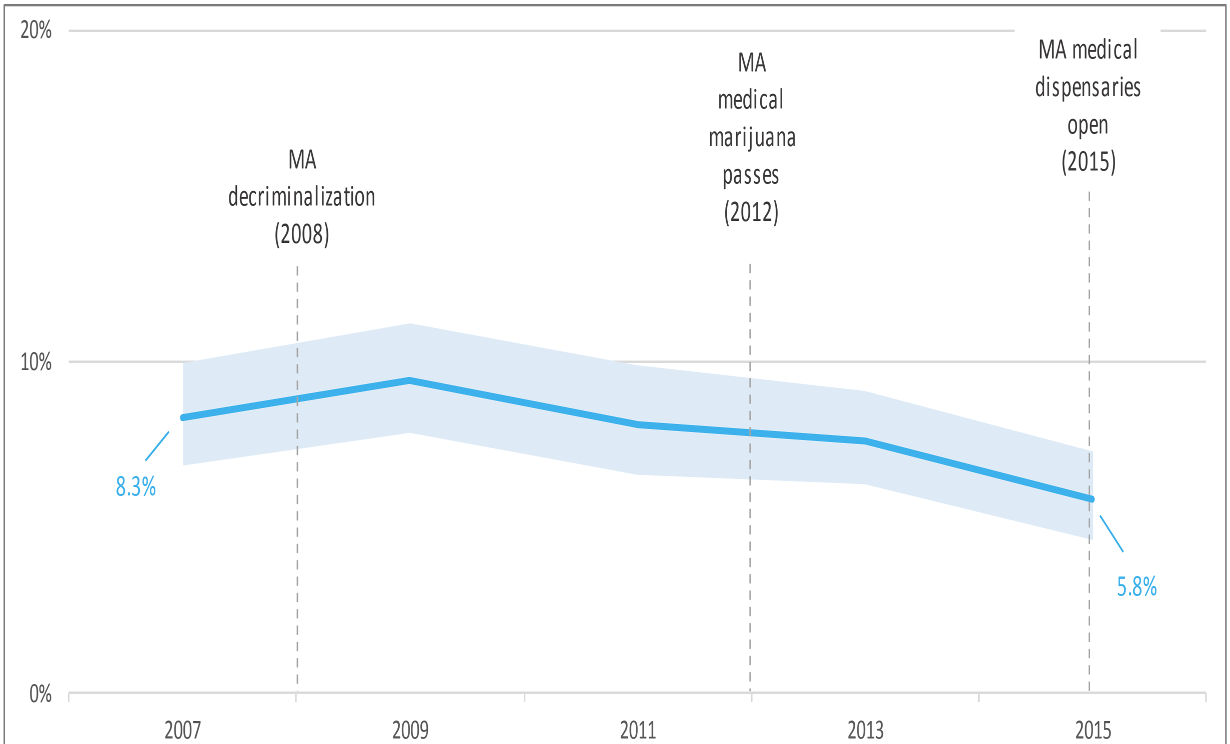
The retrospective analysis resulted in identifying 13 indicators which appear to be responsive to factors associated to marijuana legalization and sensitive to change over time. Table 2 below presents a summary of the results of the analysis.

Table 2: Retrospective Analysis Results

Youth			Adult		
Indicator	**Data Source**	**Type of Analysis**	**Indicator**	**Data Source**	**Type of Analysis**
Ever Used Marijuana - Middle School Students	YHS	F-test, p=0.002	Ever Used Marijuana - Adults Ages 18 and Older	BRFFS	F-test, p=0.000
Used Marijuana Before Age 13 - High School Students	YRBS	F-test, p=0.005	Use in the Past Year - Adults Ages 18-25	NSDUH	State comparison, non-overlapping 95% confidence intervals
Current Marijuana Use - Middle School Students	YHS	F-test, p=0.000	Use in the Past Year - Adults Ages 26+	NSDUH	State comparison, non-overlapping 95% confidence intervals
Believe Occasional Marijuana Use Poses No Risk of Harm - High School Students	YHS	F-test, p=0.000	Current Marijuana Use - Adults Ages 18-25	NSDUH	State comparison, non-overlapping 95% confidence intervals
Believe it Would Be Easy to Obtain Marijuana - High School Students	YHS	F-test, p=0.001	Current Marijuana Use - Adults Ages 26+	NSDUH	State comparison, non-overlapping 95% confidence intervals
Perceptions of Great Risk of Smoking Marijuana Once a Month, Youth Ages 12-17	NSDUH (data not available for 2014-15)	State comparison, non-overlapping 95% confidence intervals	Perceptions of Great Risk of Smoking Marijuana Once a Month, Adults Ages 18-25	NSDUH (data not available for 2014-15)	State comparison, non-overlapping 95% confidence intervals
			Perceptions of Great Risk of Smoking Marijuana Once a Month, Adults Ages 26+	NSDUH (data not available for 2014-15)	State comparison, non-overlapping 95% confidence intervals

Indicators of Youth Marijuana Use

Marijuana use among youth has generally been stable over time, both in states that have legalized recreational marijuana use and those that have not. However, data from Massachusetts suggest that marijuana use may be declining among Massachusetts middle school aged youth. Please see Figure 2 below.



	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)
MA	8.3 (6.9-10)	9.4 (7.9-11.2)	8.1 (6.6-9.9)	7.6 (6.3-9.1)	5.8 (4.6-7.3)

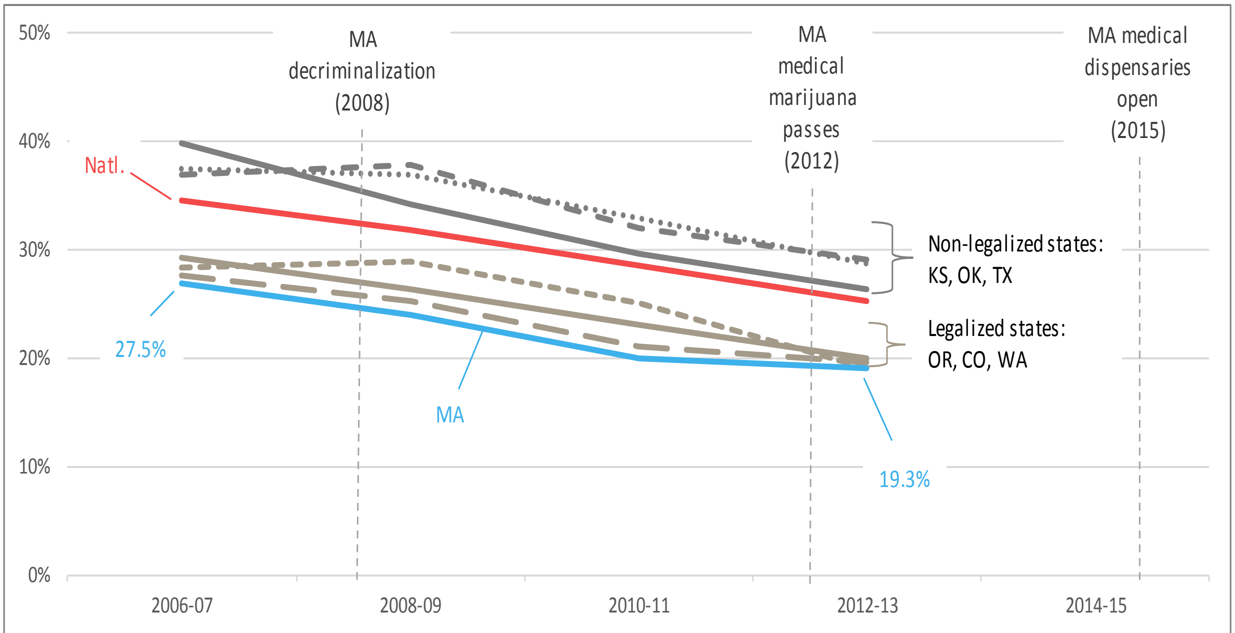
Figure 2: Massachusetts Ever Used Marijuana, Middle School Students

The specific indicators that show possible sensitivity to changes include:

- Ever Used Marijuana - Middle School Students
- Current Marijuana Use - Middle School Students
- Used Marijuana Before Age 13 - High School Students

Indicators of Youth Marijuana Perceptions

Perceptions that there is great risk in occasional marijuana use have been declining over time among youth. This trend is present in Massachusetts, nationally, and in legalized and non-legalized comparison states. More youth in non-legalized comparison states perceive that there is great risk for occasional marijuana use than youth in legalized states. Please see Figure 3 below. Massachusetts youth perceive the risk of occasional marijuana use to be lowest of all states included in analysis. In Massachusetts, this shift in perception of risk may be more pronounced in high school aged youth than in younger youth.



	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)
MA	27.5 (24.1-31.1)	24.4 (21.3-27.8)	20.5 (17.7-23.6)	19.3 (16.7-22.2)	--
Natl.	34.5 (33.9-35.1)	31.8 (31.2-32.4)	28.6 (28.0-29.2)	25.3 (24.8-25.9)	--
KS	39.9 (36.3-43.7)	34.2 (30.5-38.0)	29.6 (26.0-33.4)	26.3 (23.3-29.5)	--
OK	36.9 (33.0-41.0)	37.8 (33.9-41.9)	32.1 (28.3-36.1)	29.2 (25.8-32.8)	--
TX	37.5 (35.5-39.5)	36.9 (34.9-39.0)	32.9 (30.9-34.9)	28.6 (26.9-30.5)	--
OR	29.2 (25.8-32.9)	26.4 (23.4-29.7)	23.2 (20.1-26.5)	20.0 (17.2-23.2)	--
CO	27.7 (24.4-31.1)	25.2 (22.2-28.5)	21.1 (17.9-24.7)	19.6 (16.9-22.6)	--
WA	28.4 (25.2-31.9)	28.9 (25.9-32.2)	25.1 (21.9-28.6)	19.1 (16.5-21.9)	--

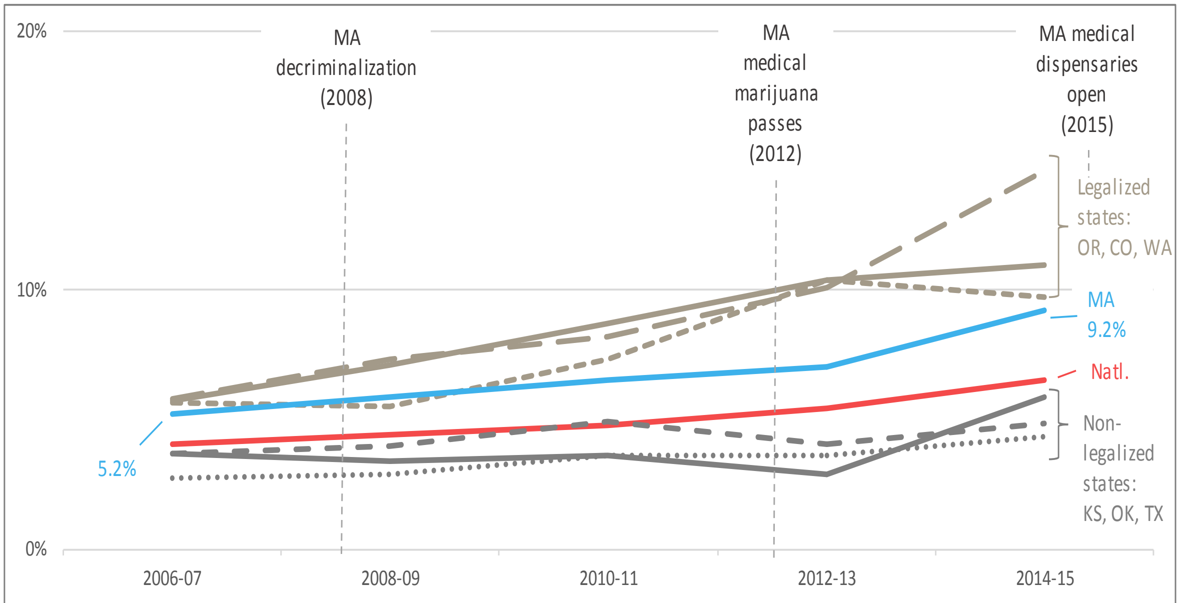
Figure 3: Massachusetts and Comparison States Perceptions of Great Risk of Smoking Marijuana Once a Month, Youth Ages 12-17

Given the parallel trends in several states, trends in these indicators may reflect larger national shifts rather than responses to state-level policy:

- Perceptions of Great Risk of Smoking Marijuana Once a Month, Youth Ages 12-17

Indicators of Adult Marijuana Use

Marijuana use seems to be increasing among some adult populations. Marijuana use among adults ages 26 and older has been increasing in Massachusetts and in states that have legalized recreational marijuana. This trend is also present nationally, though not in all non-legalized comparison states. Additionally, states that have legalized marijuana have higher rates of current use than states that do not. Finally, states that have not legalized have rates of current use that is closer to the national average. Please see Figure 4.



	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)
MA	5.2 (4.0-6.7)	5.8 (4.5-7.6)	6.6 (5.1-8.5)	7.1 (5.5-9.1)	9.2 (7.6-11.1)
Natl.	4.0 (3.8-4.3)	4.4 (4.2-4.7)	4.8 (4.5-5.1)	5.5 (5.2-5.7)	6.6 (6.3-6.8)
KS	3.7 (2.8-4.9)	3.4 (2.4-4.7)	3.6 (2.6-5.0)	2.9 (2.0-4.1)	5.8 (4.7-7.3)
OK	3.7 (2.7-5.1)	4.0 (2.8-5.5)	4.9 (3.7-6.6)	4.0 (2.9-5.6)	4.8 (3.7-6.3)
TX	2.8 (2.3-3.3)	2.9 (2.4-3.6)	3.6 (3.0-4.3)	3.6 (3.0-4.4)	4.3 (3.7-5.1)
OR	5.7 (4.4-7.3)	7.1 (5.5-9.2)	8.7 (6.9-11.0)	10.4 (8.3-12.9)	11.0 (9.2-13.0)
CO	5.8 (4.5-7.5)	7.3 (5.6-9.5)	8.2 (6.4-10.4)	10.1 (8.1-12.6)	14.6 (12.4-17.2)
WA	5.6 (4.4-7.2)	5.5 (4.2-7.3)	7.3 (5.8-9.2)	10.4 (8.5-12.7)	9.7 (8.0-11.8)

Figure 4: Massachusetts and Comparison States Current Use Ages 26 and Older

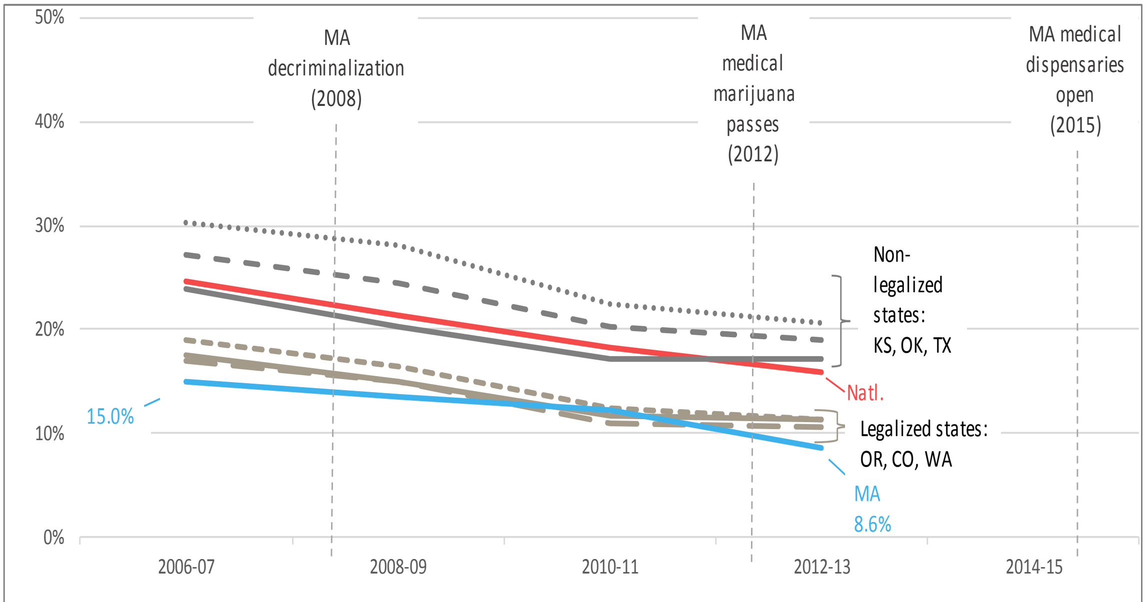
Among adults ages 18-25, who have higher rates of marijuana use than their older counterparts, use has increased in some legalized states but not in Massachusetts. Overall rates of use for all adults ages 18 and older have increased in Washington State, where recreational marijuana is legal.

The specific indicators that show possible sensitivity to policy changes include:

- Current Marijuana Use - Adults Ages 18-25 and Adults Ages 26+
- Use in the Past Year - Adults Ages 18-25 and Adults Ages 26+
- Current Marijuana Use - Adults Ages 18 and Older
- Ever Used Marijuana - Adults Ages 18 and Older

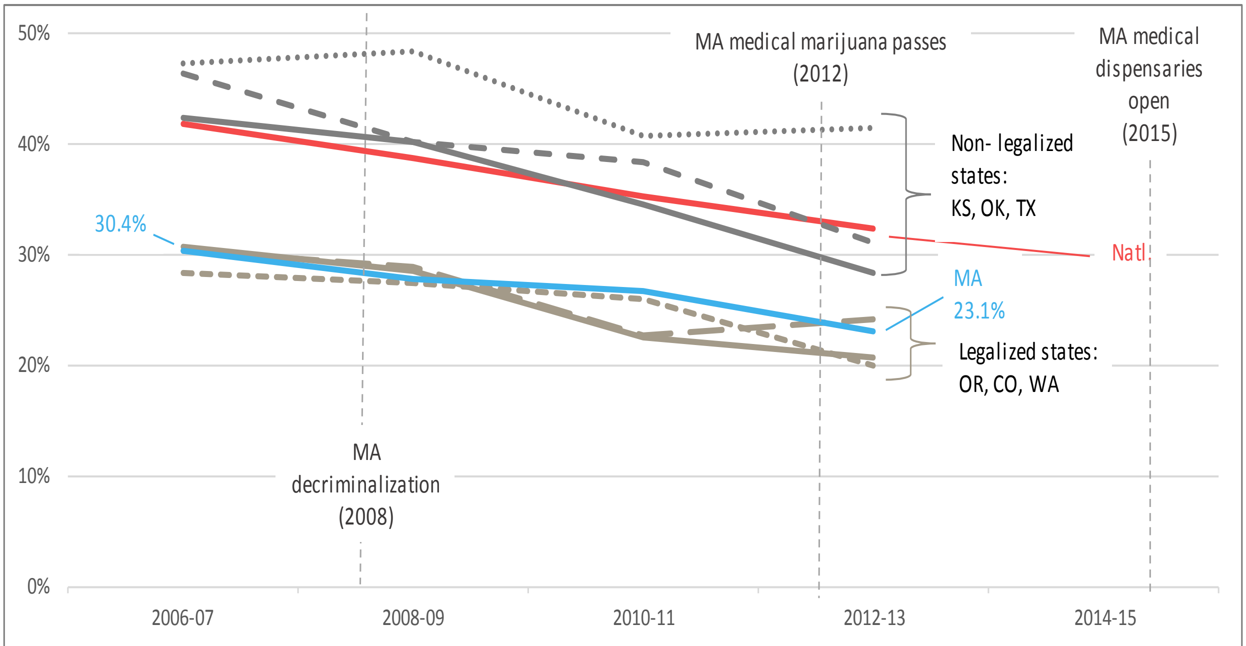
Indicators of Adult Marijuana Perceptions

As with youth, perceptions about the risks of marijuana use among adults seem to be shifting; fewer adults believe there is great risk in occasional use. This trend is occurring in Massachusetts, nationally, and in legalized and non-legalized states. Those adults in non-legalized states perceive the risk of occasional use to be higher than those in legalized states. Massachusetts adults' perceptions were closer to those in legalized comparison states than non-legalized. Please see Figures 5 and 6 below.



	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)
MA	15.0 (12.6-17.8)	13.5 (11.2-16.2)	12.3 (10.1-14.8)	8.6 (6.8-10.6)	--
Natl.	24.6 (24.0-25.2)	21.3 (20.7-21.9)	18.3 (17.7-18.8)	15.8 (15.3-16.3)	--
KS	23.8 (20.5-27.5)	20.3 (17.5-23.4)	17.2 (14.7-20.0)	17.1 (14.5-20.1)	--
OK	27.2 (23.7-31.1)	24.4 (21.2-27.9)	20.3 (17.4-23.7)	19.0 (16.2-22.2)	--
TX	30.3 (28.4-32.3)	28.2 (26.3-30.1)	22.5 (20.8-24.2)	20.7 (19.1-22.4)	--
OR	17.6 (15.0-20.6)	15.0 (12.8-17.5)	11.6 (9.6-14.0)	11.3 (9.3-13.8)	--
CO	17.1 (14.4-20.1)	14.9 (12.6-17.7)	10.9 (8.9-13.3)	10.7 (8.7-13.1)	--
WA	18.9 (16.2-22.0)	16.4 (13.9-19.1)	12.4 (10.4-14.9)	11.3 (9.4-13.7)	--

Figure 5. Massachusetts and Comparison States Perceptions of Great Risk of Smoking Marijuana Once a Month, Adults Ages 18-25



	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)	% (confidence intervals)
MA	30.4 (27.0-34.0)	27.9 (24.5-31.5)	26.7 (23.4-30.3)	23.1 (19.8-26.6)	--
Natl.	41.9 (41.2-42.6)	38.7 (38.1-39.4)	35.2 (34.5-35.9)	32.4 (31.8-33.1)	--
KS	42.4 (38.9-46.0)	40.2 (36.3-44.2)	34.5 (31.0-38.3)	28.4 (24.8-32.3)	--
OK	46.4 (42.4-50.4)	40.1 (35.9-44.5)	38.5 (34.7-42.3)	31.0 (27.2-35.1)	--
TX	47.4 (45.3-49.5)	48.4 (46.1-50.7)	40.8 (38.6-43.0)	41.5 (39.4-43.6)	--
OR	30.7 (27.6-34.1)	28.5 (25.0-32.2)	22.6 (19.5-26.0)	20.8 (17.7-24.3)	--
CO	30.5 (27.1-34.0)	28.9 (25.3-32.8)	22.7 (19.8-26.0)	24.2 (20.9-27.8)	--
WA	28.3 (25.0-31.8)	27.5 (24.2-31.1)	25.9 (22.6-29.5)	19.9 (17.0-23.1)	--

Figure 6: Massachusetts and Comparison States Perceptions of Great Risk of Smoking Marijuana Once a Month, Adults Ages 26+

Given the parallel trends in several states, trends in these indicators may reflect larger national shifts rather than responses to state-level policy:

- Perceptions of Great Risk of Smoking Marijuana Once a Month - Adults Ages 18-25 and Adults Ages 26+

Discussion

Massachusetts rates and trends consistently reflected those in comparison states that have legalized marijuana (Colorado, Oregon and Washington). And likewise legal states' trends (Kansas, Texas and Oklahoma), when comparisons were available, were different from trends in non-legal states. This suggests that some indicators may be responsive to factors associated with legalization of marijuana. The 6 indicators, 2 youth and 4 adult indicators, that differentiated between legal and non-legalized comparison states include:

- Used Marijuana Before Age 13, High School Students
- Perceptions of Great Risk of Smoking Marijuana Once a Month, Youth Ages 12-17
- Current Marijuana Use, Adults Ages 26+
- Use in the Past Year, Adults Ages 26+
- Perceptions of Great Risk of Smoking Marijuana Once a Month, Adults Ages 18-25
- Perceptions of Great Risk of Smoking Marijuana Once a Month, Adults Ages 26+

In some cases, the exact items from which the indicators are drawn, were not available for other states. For these indicators, analysis of the trends in response to policy changes was conducted. The study identified 7 indicators, 4 youth indicators and 3 adult indicators, which appear to be responsive to changes over time. These indicators include:

- Ever Used Marijuana - Middle School Students
- Current Marijuana Use - Middle School Students
- Believe Occasional Marijuana Use Poses No Risk of Harm - High School Students
- Believe it Would Be Easy to Obtain Marijuana - High School Students
- Current Marijuana Use - Adults Ages 18-25
- Use in the Past Year - Adults Ages 18-25
- Ever Used Marijuana - Adults Ages 18 and Older

One indicator, Current Marijuana Use - Adults Ages 18 and Older, was only available for Washington State and therefore it is difficult to assert that similar trends would be evident in Massachusetts. The data sets utilized were helpful when considering trends in use, consumption, and perceptions of marijuana for health and policy-related purposes. While these data are rich information, consistency with regard to the availability of the data and wording of the questions make drawing state comparisons challenging.

References

Allen, J., & Holder, M. D. (2014). Marijuana use and well-being in university students. *Journal of Happiness Studies*, *15*(2), 301–321. https://doi.org/10.1007/s10902-013-9423-1.

Arria, A. M., Caldeira, K. M., O'Grady, K. E., Vincent, K. B., Fitzelle, D. B., Johnson, E. P., & Wish, E. D. (2008). Drug exposure opportunities and use patterns among college students: results of a longitudinal prospective cohort study. *Subst Abus, 29*(4), 19-38. doi: 10.1080/08897070802418451.

Bachhuber MA, Saloner B, Cunningham CO, Barry CL. (2014) Medical cannabis laws and opioid analgesic overdose mortality in the United States, 1999-2010. *JAMA Intern Med,* Oct;174(10):1668-73.

Buckner, J. D. (2013). College cannabis use: the unique roles of social norms, motives, and expectancies. *J Stud Alcohol Drugs, 74*(5), 720-726.

Budney, A.J., Moore, B.A. (2002). Development and consequences of cannabis dependence. *Journal of Clinical Pharmacology*, 42(11 Supplement): 28S-33S.

Cambron, C., Guttmannova, K., & Fleming, C. B. (2017). State and national contexts in evaluating cannabis laws: A case study of Washington State. *Journal of Drug Issues*, 47(1), 74–90. https://doi.org/10.1177/0022042616678607.

Caulkins, J.P. (2018). The real dangers of marijuana. *National Affairs,* 35. Retrieved from https://www.nationalaffairs.com/publications/detail/the-real-dangers-of-marijuana.

Chen, P., & Jacobson, K. C. (2012). Developmental trajectories of substance use from early adolescence to young adulthood: gender and racial/ethnic differences. *J Adolesc Health, 50*(2), 154-163. doi: 10.1016/j.jadohealth.2011.05.013.

Cook, S. H., Bauermeister, J. A., Gordon-Messer, D., & Zimmerman, M. A. (2013). Online network influences on emerging adults' alcohol and drug use. *J Youth Adolesc, 42*(11), 1674-1686. doi: 10.1007/s10964-012-9869-1.

DeWit, D. J., Offord, D. R., & Wong, M. (1997). Patterns of onset and cessation of drug use over the early part of the life course. *Health Educ Behav, 24*(6), 746-758.

Fihn, S.D., Francis, J., Clancy, C., Nielson, C., Nelson, K., Rumsfeld, J., Cullen, T., Bates, J., Graham, G.L. (2014). Insights from advanced analytics at the Veterans Health Administration. *Health Affairs (Millwood)*, 33(7): 1203-1211.

Gordon, A.J., Conley, J.W., Gordon, J.M. (2013). Medical consequences of marijuana use: a review of current literature. *Current Psychology Reports*, 15(12): 419.

Halamka, J. (2007, November 12). Data, information, knowledge, and wisdom. [Web log post]. Retrieved from http://geekdoctor.blogspot.com/2007/11/data-information-knowledge-and-wisdom.html.

Hall, W., Degenhardt, L. (2014). The adverse health effects of chronic cannabis use. *Drug Testing and Analysis*, 6(1-2): 39-45.

Hall, W. & Degenhardt, L. (2009). Adverse health effects of non-medical cannabis use. *Lancet*, 374, 1383–1391.

Hall, W. & Kozlowski, L.T. (2015). The diverging trajectories of cannabis and tobacco policies in the United States: reasons and possible implications. *Addiction*, 313(3), 241–242. https://doi.org/10.1038/nbt.3121.ChIP-nexus.

Hasin DS, Sarvet AL, Cerdá M, Keyes KM, Stohl M, Galea S, Wall MM. (2017) US Adult

Illicit Cannabis Use, Cannabis Use Disorder, and Medical Marijuana Laws: 1991-1992 to 2012-2013. *JAMA Psychiatry,* Jun 1;74(6):579-588.
Inaba DS & Cohen WE. Uppers, downers, all arounders. Seventh Edition. CNS Productions, Inc. Medford OR.
Kandel, D. B., & Chen, K. (2000). Types of marijuana users by longitudinal course. *J Stud Alcohol, 61*(3), 367-378.
Keyes, K. M., Wall, M., Cerdá, M., Schulenberg, J., O'Malley, P. M., Galea, S., Hasin, D.S. (2016). How does state marijuana policy affect US youth? Medical marijuana laws, marijuana use and perceived harmfulness: 1991–2014. *Addiction*, *111*(12), 2187–2195. https://doi.org/10.1111/add.13523.
Longhurst, C.A., Harrington, R.A., Shah, N.H. (2014). A 'green button' for using aggregate patient data at the point of care. *Health Affairs (Millwood)*, 33(7): 1229-1235.
Martins SS, Mauro CM, Santaella-Tenorio J, Kim JH, Cerda M, Keyes KM, Hasin DS, Galea S, Wall M. (2016). State-level medical marijuana laws, marijuana use and perceived availability of marijuana among the general U.S. population. *Drug Alcohol Depend*. Dec 1; 169:26-32.
McCabe, S. E. (2008). Misperceptions of non-medical prescription drug use: a web survey of college students. *Addict Behav, 33*(5), 713-724. doi: 10.1016/j.addbeh.2007.12.008.
Monte, A. A., Zane, R. D., & Heard, K. J. (2015). The implications of marijuana legalization in Colorado. *JAMA*, *313*(3), 241–242. https://doi.org/10.1038/nbt.3121.ChIP-nexus.
Olfson M, Wall MM, Liu SM, Blanco C. (2018). Cannabis Use and Risk of Prescription Opioid Use Disorder in the United States. *Am J Psychiatry*. Jan 1;175(1):47-53.
Pacula, R.L., Kilmer, B., Wagenaar, A.C., Chaloupka, F.J., Caulkins, J.P. (2014). Developing public health regulations for marijuana: lessons from alcohol and tobacco. *American Journal of Public Health*, 104(6): 1021-1028.
Pacula, R.L., MacCoun, R., Reuter, P., Chriqui, J., Kilmer, B., Harris, K., Paoli, L., Schäfer, C. (2005). What does it mean to decriminalize marijuana? A cross-national empirical examination. *Advances in Health Economics and Health Services Research*, 16: 347-369.
Pew Research Center. (2014). America's new drug policy landscape: Two-thirds favor treatment, not jail, for use of heroin, cocaine.
Pischke, C. R., Zeeb, H., van Hal, G., Vriesacker, B., McAlaney, J., Bewick, B. M., . . . Mikolajczyk, R. T. (2012). A feasibility trial to examine the social norms approach for the prevention and reduction of licit and illicit drug use in European University and college students. *BMC Public Health, 12*, 882. doi: 10.1186/1471-2458-12-882.
Powell D, Pacula RL, Jacobson M. (2018). Do medical marijuana laws reduce addictions and deaths related to pain killers? *J Health Econ,* Jan 30;58:29-42.
Schulenberg JE, Merline AC, Johnston LD, O'Malley PM, Bachman JG, Laetz VB. (2005). Trajectories of Marijuana Use During the Transition to Adulthood: The Big Picture Based on National Panel Data. *J Drug Issues,* 35(2):255-279.
Substance Abuse and Mental Health Services Administration. (2017). Key substance use and mental health indicators in the United States: Results from the 2016

National Survey on Drug Use and Health (HHS Publication No. SMA 17-5044, NSDUH Series H-52). Rockville, MD: Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration. Retrieved from https://www.samhsa.gov/data/.

Swift, A. (2013). For first time Americans favor legalizing marijuana. Retrieved from: www.gallup.com.

Swift, W., Coffey, C., Degenhardt, L., Carlin, J. B., Romaniuk, H., & Patton, G. C. (2012). Cannabis and progression to other substance use in young adults: findings from a 13-year prospective population-based study. *J Epidemiol Community Health, 66*(7), e26. doi: 10.1136/jech.2010.129056.

Tai, B., Hu, L., Ghitza, U.E., Sparenborg, S., Van Veldhuisen, P., Lindblad, R. (2014). Patient registries for substance use disorders. *Substance Abuse and Rehabilitation*, 5: 81-86.

Tzilos, G. K., Reddy, M. K., Caviness, C. M., Anderson, B. J., & Stein, M. D. (2014). Getting higher: co-occurring drug use among marijuana-using emerging adults. *J Addict Dis, 33*(3), 202-209. doi: 10.1080/10550887.2014.950024.

Volkow, N.D., Baler, R.D., Compton, W.M., Weiss, S.R.B. (2014). Adverse Health Effects of Marijuana Use. *The New England Journal of Medicine*, 370: 2219-2227.

Vyas MB, LeBaron VT, Gilson AM. (2018). The use of cannabis in response to the opioid crisis: A review of the literature. *Nurs Outlook,* Jan - Feb;66(1):56-65.

Weil, A.R. (2014). Big data in health: a new era for research and patient care. *Health Affairs (Millwood)*, 33(7): 1110.

Zou, G. (2004). A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol, 159*(7), 702-706.

Chapter 2: Prevalence and Correlates of Marijuana Use among Adults in Massachusetts

Introduction

In this Chapter, we report on prevalence of marijuana use among adults in Massachusetts, the characteristics of marijuana users compared with non-users, and the correlates of marijuana use. Findings are based on data provided by Massachusetts adults who completed a survey in the fall of 2017. Despite the existence of several ongoing surveys of Massachusetts adults, such as the Behavioral Risk Factor Surveillance Survey (BRFSS) and the National Survey on Drug Use and Health (NSDUH), there are significant gaps in the information that they provide. For example, existing Massachusetts databases did not provide information about various modes of consumption (from smoking, to eating, to vaping and dabbing).

The purpose of this survey was to address these gaps and provide a "snapshot" of marijuana use and related behaviors in Massachusetts in the time before retail sales of adult use marijuana begin. This study provides a "baseline" or benchmark against which future studies can make comparisons. The information from this survey will enable ongoing study of impacts that can inform the Commonwealth's policy and regulatory response over the course of the next several years.

Methods

We conducted a cross-sectional, population-based survey of adults in Massachusetts. This study was approved by the Institutional Review Board at the Massachusetts Department of Public Health. A copy of the survey instrument can be found in the Appendix A.

Data Collection and Participants

The University of Massachusetts Amherst partnered with the University of Massachusetts Donahue Institute to conducted a mail and web-based survey designed to be representative of adults in Massachusetts, age 18 years or older. Participants were chosen randomly using address-based sampling from a list of Massachusetts residential households obtained through a sampling vendor. The sample was stratified by 6 regions (Boston, Central, Metrowest, Northweast, Southeast, and Western). Addresses that were known to be vacant, seasonal, educational, or drop points were excluded from the sample. A simple random sample of 15,000 addresses were selected to participate with an equal number of households (n=2500) selected from each region. The survey was then administered in four waves over a four-week period.

Wave 1: Pre-notification postcard

A pre-notification postcard was sent to selected addresses informing participants about the survey eligibility to participate. On the postcard and all subsequent mailings an online survey link with a unique access code was provided for those who chose to complete the web-based version. Online survey participants could only complete the survey once, and quality checks were implemented to identify duplicate completions (by mail and online) using the same code. The postcard and all subsequent materials included a means to opt out of participation by calling the researchers.

Wave 2: Mail Survey

The postcard was followed by a survey packet containing an informed consent letter, the full survey, a postage-paid business reply envelope, and an up-front cash incentive of $2. The survey instructed the adult in the household with the most recent birthday to complete the survey. Responses were tracked with a unique identification number to allow for follow-up mailings.

Wave 3: Reminder Postcard

After the initial wave of survey mailing, a reminder postcard with the online link was sent to all non-responders.

Wave 4: Final Mail Survey

The final opportunity to respond was via paper-based survey with the informed consent cover letter and online link. This was sent to those who still had not responded or had not notified the researchers of their desire not to participate.

Data were collected between November 7, 2017 (first online response opportunity) and December 30, 2017. Completed mail surveys were scanned using a computerized system. The scanned dataset was combined with the online responses and an initial quality review removed all duplicate surveys from the dataset. The resultant dataset included 3,023 respondents with a 21.7% response rate.

Measures

The survey contained 37 items that assessed a limited number of demographic characteristics, past 30-day substance use (marijuana, alcohol, and other substances), and behaviors related to substance use such as driving under the influence and riding with a driver who was under the influence. When possible the wording of items was aligned with national population health surveys (e.g. Behavioral Risk Factor Surveillance Survey, National Survey on Drug Use and Health) to facilitate comparisons of estimates.

Demographic characteristics

Basic demographics were ascertained. Participant age was ascertained by asking the survey respondent to report their year of birth. Participants reported gender as female, male, or other. Race/ethnicity was asked with two questions. One asked “Are you Hispanic or Latino?” and required a yes/no response. The second question asked “Which one or more of the following would you say is your race?” with response options that included (1) white or Caucasian, (2) Black or African American, (3) Asian, (4) Native

Hawaiian or Other Pacific Islander, (5) Native American or Alaska Native, (6) Some other race. Participants could choose as may categories as were applicable. The survey ascertained the participants' highest degree or level of school completed, which was reported on the survey with 10 categories ranging from "never attended school or only attended kindergarten" to "doctorate degree". For analysis, this was coded to a 3-level variable that included: (1) high school or less, (2) any college, (3) graduate degree. The survey asked about annual household income using the following categories (1) less than $15,000 (2) $15-29,000 (3) $30,000-49,000 (4) 50,000-99,000 (5) 100,000-150,000, or (6) 150,000 or more. Participants also reported zip code as well as home ownership (own, rent, something else). Participants reported their type of healthcare coverage as one or more of the following (1) private commercial or group plan (2) Medicare, (3) Medicaid, (4) Commonwealth Care Program (Health Connector), (5) Indian Health Service (6) Veterans Affairs (7) No health insurance, or (8) other plan.

Substance Use

The survey ascertained past 30-day use of marijuana, alcohol, and other substances. Marijuana use was assessed with the yes/no question "In the past 30 days, did you use marijuana or hashish at least once?" For those who responded "yes," the survey asked about the number of days on which the participated used marijuana in the past 30 days. The purpose of marijuana use was ascertained with a multiple response item indicating use for one or more of the following: adult use (non-medical), medical use (prescribed by a qualified physician), or medical use (not prescribed by a qualified physician). The mode of use (smoking, eating, drinking, vaporizing, etc.) was assessed with a multiple response item.

Past 30-day alcohol use was reported with the yes/no question "During the past 30 days, did you have at least one drink of any alcoholic beverage such as beer, wine, a malt beverage, or liquor?" For those who responded "yes," the survey asked them to provide the number of days per week that participants consumed an alcoholic beverage. Use of other substances was coded as "Yes" if participants reported use of crack/cocaine, heroin, non-medical use of antianxiety drugs (sedatives, tranquilizers, anxiolytics, or sleeping drugs such as benzodiazepines or barbiturates), non-medical use of prescription opioids, or other drugs (e.g. hallucinogens, non-medical use of stimulants). The instructions to participants in the section of the survey on other substances noted that "non-medical" prescription drug use means using it to get high or experience pleasurable effects, see what the effects are like, or use with friends. Items and results pertaining to driving under the influence of marijuana, alcohol, and other drugs are reported in Task 2 of this report, along with items pertaining to use of hospital emergency rooms and urgent care related to substance use.

Data Quality Assessment

The data was subject to a quality check process. Duplicates were identified and removed, leaving 3268 respondents. We verified that skip logic was properly applied. Other instances with out-of-range responses (e.g. reported having 33 children in the home) were also coded as missing. Any instances in which returned responses were unreasonable were coded as a missing response on the illogical variable. In cases in which a respondent reported driving under the influence of a substance, but did not first report using that substance, we set the response to the question about use to yes. This affected a very small number of cases.

Statistical Procedures and Analysis

Weighting

Weights were assigned to each completed survey so that the survey responses closely represent the Massachusetts population relative to age, gender, race, and education. The weighting scheme included six steps that are summarized below.
First, a weight was assigned to directly account for the sampling fraction of addresses. Second, using information on the sample addresses, adjustments were made for unknown eligibility of the addresses. Eligibility was classified into one of four categories: (1) eligible respondent, (2) eligible non-respondent, (3) known ineligible addresses, and (4) unknown status. Eligible respondents resided at the sample address, were 18 years or older, and lived in Massachusetts for 6 or more months per year. Addresses with unknown status included addresses where surveys were not returned (n=11,163), surveys bounced back to the post office (presumably based on refusal of recipient) (n=504), and surveys returned blank (n=65). The eligibility weighting accounted for the fact that our knowledge of eligibility status may be related to other address characteristics such as the type of postal route (rural, street, firm, high-rise, etc.).
The third step in the weighting was to adjust for non-response. We defined a complete survey as one in which the respondent provided basic demographics (age, gender, race, and education) and answered the item on past 30-day marijuana use. We observed a difference in the survey completion rate for eligible addresses by region (p=0.03) and a weight was developed to account for this. Household size was accounted for next.

Raking was then used to align the weights to the distribution of four demographic variables (age, gender, race/ethnicity, and education) to the Massachusetts target population based on the 2016 American Community Survey Public Use Microdata Sample (PUMS) data. The last step trimmed weights to improve estimation accuracy.

Statistical Analysis

In most cases, variables were defined as shown on the survey. For example, past 30-day marijuana use was defined as “Yes” based on an answer of yes to the question, “In the past 30 days, did you use marijuana or hashish at least once?” For analysis purposes, we coded race as a 5-level categorical variable with the following categories (1) White, non-Hispanic, (2) Black non-Hispanic, (3) Any Hispanic/Latino (4) Asian, non-Hispanic, (5) Other.

First, we examined the bivariate differences in characteristics between adults who had used marijuana in the past 30 days and those who had not. Next, we used modified

Poisson regression with robust standard errors (Zou, 2004) to assess associations between use of marijuana (yes/no), gender, age, race/ethnicity, and other covariates (education, home ownership, children in household, region, alcohol and other substance use). This approach allowed estimation of relative risk, adjusting for potential confounders. We used a two-tailed significance level at p <0.05 for all statistical tests. All analyses were weighted to account for the complex survey design, yielding results that have been adjusted to be representative of the adult population in Massachusetts. The analysis for this report was generated using SAS/STAT software, Version 9.4 of the SAS System for Windows (Copyright © 2016 SAS Institute Inc. Cary, NC, USA.) with the exception of the Poisson regression models which were generated using Stata 15 statistical software (StataCorp, LLC, College Station, TX).

Results

A total of 3,528 surveys were returned, of which 260 were duplicates. And additional 245 were determined ineligible or incomplete. After removing the duplicate, ineligible and complete surveys, 3,023 remained. The logic-checking process resulted in identification of one case in which multiple questions had unreasonable responses. This case was dropped, resulting in a final analytic sample of 3,022.

Prevalence of Marijuana Use

Of the 3,022 adults in the sample, 439 self-reported marijuana use in the past 30 days, and 2,583 did not. After data were weighted, results indicate that 21.1% of adults in Massachusetts have used marijuana in the past 30 days (95% Confidence Interval [CI] 18.6, 23.6), and 78.9% have not (95% CI 76.4, 81.4) (Table 1). Hereafter, we report only the population-level point estimates; confidence interval data are presented in each table.

We examined prevalence rates of past 30-day marijuana use among key socio-demographic groups. These analyses indicated that 25.9% of adult men in Massachusetts and 17.0% of women have used marijuana in the past 30 days.
By age category, past 30-day marijuana use was reported by 54.4% of adults aged 18 to 20, 49.1% of those aged 21 to 25, 34.5% of those aged 26 to 29, 22.7% of those aged 30 to 39, 19.3% of those aged 40 to 49, 18.7% of those aged 50 to 59, 14.1% of those aged 60 to 69, and 3.4% of those aged 70 or older. To enable comparisons of age-specific marijuana prevalence with other estimates (presented in Chapter 1), we changed the categorization of age to create a category that captured aged 26 or older. Past 30-day marijuana use was reported by 18.0% (95% CI 15.7, 20.3) of adults aged 26 or older. By race/ethnicity, past 30-day marijuana use was reported by 20.1% of Whites, 27.1% of Hispanics, 10.4% of Asians, 25.8% of Blacks, and 37.5% of other race/ethnic groups. By educational attainment, past 30-day marijuana use was reported by 24.7% of adults with a High School education or less, 22.9% of those with a college degree, and 10.7% of adults with a post-secondary graduate degree. By income, past 30-day marijuana use was reported by 32.5% of adults earning less than $15,000. Fewer people in each of the higher income categories reported past 30-day use, with

prevalence rates ranging between about 17.3% and 25%. By region, past 30-day marijuana use was reported by 29.8% of Western residents, 20.9% of Southeast residents, 20.5% of Boston residents, 20.1% of Northeast residents, 19.6% of Central residents, and 18.2% of Metrowest residents.

Socio-Demographic Characteristics

Table 2 presents socio-demographic characteristics of adults who had used marijuana in the past 30 days compared with adults who had not. A greater proportion of marijuana users than non-users are men, 57.7% versus 44.5% ($p<0.001$).
With respect to age, marijuana users tend to be younger than non-users, with a greater proportion of them in the youngest age categories ($p<0.001$). Specifically, 9.6% of marijuana users are aged 18 to 20, versus 2.2% of non-users, 14.7% of marijuana users are 21 to 25, versus 4.2% of non-users, and 14.3% of marijuana users are 26 to 29, versus 7.4% of non-users. For the 30 to 59 age categories, differences between marijuana users and non-users are small (<5%). A smaller proportion of marijuana users than non-users are aged 60 to 69, 10.1% versus 16.7%, and a smaller proportion are 70 or older, 2.3% versus 17.2%.

A smaller proportion of marijuana users than non-users are White or Asian, and a greater proportion are Hispanic, African American, or other race/ethnicity ($p<0.05$). Specifically, 70.8% of marijuana users are White, versus 75.5% of non-users, and 3.2% of marijuana users are Asian, versus 7.3% of non-users. Among marijuana users, 12.0% are Hispanic, 7.1% are African American, and 6.9% are another race/ethnicity. Among non-users, in comparison, 8.7% are Hispanic, 5.5% are African American, and 3.1% are another race/ethnicity.

Table 1. Prevalence Rate of Past 30-day Marijuana Use by Key Socio - Demographic Characteristics

	%	95% CI	
Total population	21.1	18.6	23.6
Gender			
Female	17.0	14.1	20.0
Male	25.9	21.9	29.9
Age			
18-20	54.4	32.3	76.4
21-25	49.1	35.1	63.1
26-29	34.5	23.6	45.5
30-39	22.7	16.7	28.7
40-49	19.3	12.8	25.8
50=59	18.7	14.9	22.5
60-69	14.1	10.4	17.8
>=70	3.4	1.0	5.9
Race/Ethnicity			
White, non-Hispanic	20.1	17.5	22.8
Hispanic	27.1	16.7	37.5
Asian, non-Hispanic	10.4	2.7	18.2
Black, non-Hispanic	25.8	12.1	39.5
Other, non-Hispanic	37.4	21.9	52.9
Education			
<=HS	24.7	19.1	30.3
College	22.9	19.6	26.1
Graduate degree	10.7	7.9	13.4
Income			
Less than $15,000	32.5	22.7	42.4
$15,000 - $29,999	24.6	16.2	33.1
$30,000 - $49,999	17.3	11.2	23.4
$50,000 - $99,999	20.7	16.0	25.4
$100,000 - $149,999	21.5	15.7	27.3
$150,000 or more	19.8	13.9	25.7
Region			
Boston	20.5	13.8	27.2
Central	19.6	14.0	25.3
Metrowest	18.2	12.6	23.7
Northeast	20.1	14.6	25.7
Southeast	20.9	14.7	27.2
Western	29.8	23.2	36.4

A greater proportion of marijuana users than non-users have attained a High School diploma or college degree, and a smaller proportion have attained a graduate degree ($p<0.001$). A smaller proportion of marijuana users than non-users own a home, and a greater proportion rent or have another type of living arrangements ($p<0.001$).

There are no differences between marijuana users and non-users in the remaining socio-demographic characteristics, including income, having children in the home, health insurance type, and region of residence. For both groups, most report an income of $50,000 to $99,999 or more, few have children in the home, private health insurance is the most common type of health insurance, followed by Medicare and Mass Health.

Table 2. Socio-Demographic Characteristics of Marijuana Users and Non-Users

	In the past 30 days, did you use marijuana or hashish at least once?								
	Yes: n=439, 21.1% (95% CI 18.6, 23.6)			**No: n=2,583, 78.9%** (95% CI 76.4, 81.4)			**Total: n=3,022**		
	%	**95% CI**		**%**	**95% CI**		**%**	**95% CI**	
Gender* **									
Female	42.3	35.6	48.9	55.5	52.7	58.4	52.7	50.0	55.4
Male	57.7	51.1	64.4	44.5	41.6	47.3	47.3	44.6	50.0
Age***									
18-20	9.6	4.2	15.0	2.2	0.8	3.6	3.8	2.1	5.4
21-25	14.7	9.5	20.0	4.2	2.5	5.8	6.4	4.7	8.1
26-29	14.3	9.1	19.6	7.4	5.5	9.2	8.9	7.0	10.7
30-39	18.1	13.1	23.2	16.8	14.4	19.1	17.0	14.9	19.2
40-49	15.5	10.0	20.9	17.6	15.2	19.9	17.1	15.0	19.3
50-59	15.3	11.8	18.9	18.0	16.1	19.9	17.5	15.8	19.1
60-69	10.1	7.2	13.1	16.7	15.0	18.4	15.3	13.8	16.8
>=70	2.3	0.6	3.9	17.2	15.5	18.9	14.0	12.6	15.4
Race/Ethnicity*									
White, non-Hispanic	70.8	64.0	77.7	75.4	72.6	78.3	74.5	71.8	77.1
Hispanic	12.0	7.0	16.9	8.7	6.4	10.9	9.4	7.3	11.4
Asian, non-Hispanic	3.2	0.7	5.7	7.3	5.6	9.0	6.4	5.0	7.8
Black, non-Hispanic	7.1	2.7	11.6	5.5	4.0	7.0	5.8	4.3	7.4
Other, non-Hispanic	6.9	3.1	10.7	3.1	2.1	4.1	3.9	2.8	5.0
Education***									
<=HS	38.4	31.1	45.7	31.9	28.8	34.9	33.2	30.4	36.1
College	53.1	46.1	60.1	48.8	45.9	51.6	49.7	47.0	52.4
Graduate degree	8.5	6.1	10.9	19.4	17.6	21.1	17.1	15.5	18.6
Income									
Less than $15,000	15.9	10.3	21.4	9.2	7.2	11.1	10.6	8.7	12.6
$15,000 - $29,999	11.2	6.9	15.6	9.6	7.8	11.3	9.9	8.2	11.6
$30,000 - $49,999	12.7	8.0	17.4	16.9	14.5	19.3	16.0	13.8	18.1
$50,000 - $99,999	27.3	21.1	33.6	29.2	26.6	31.7	28.8	26.4	31.2
$100,000 - $149,999	17.5	12.5	22.6	17.8	15.6	20.1	17.8	15.7	19.9
$150,000 or more	15.4	10.4	20.4	17.4	15.4	19.3	16.9	15.1	18.8

(Continued) Table 2. Socio-Demographic Characteristics of Marijuana Users and Non-Users

	In the past 30 days, did you use marijuana or hashish at least once?								
	Yes: n=439, 21.1% (95% CI 18.6, 23.6)			**No: n=2,583, 78.9%** (95% CI 76.4, 81.4)			**Total: n=3,022**		
	%	**95% CI**		**%**	**95% CI**		**%**	**95% CI**	
Home ownership* **									
Own	44.2	37.6	50.9	63.6	60.7	66.6	59.5	56.8	62.3
Rent	46.6	39.7	53.6	30.7	27.9	33.5	34.1	31.4	36.8
Something else	9.1	4.4	13.8	5.7	3.9	7.4	6.4	4.7	8.1
Children in household									
No	71.4	64.8	78.0	68.4	65.5	71.2	69.0	66.4	71.7
Yes	28.6	22.0	35.2	31.6	28.8	34.5	31.0	28.3	33.6
Multiple	10.2	5.8	14.6	15.5	13.8	17.3	14.4	12.8	16.1
Region									
Boston	13.8	9.0	18.6	14.3	12.1	16.4	14.2	12.2	16.2
Central	13.3	9.1	17.5	14.6	12.7	16.4	14.3	12.6	16.0
Metrowest	18.3	12.6	24.0	22.1	19.8	24.5	21.3	19.1	23.6
Northeast	17.4	12.3	22.4	18.4	16.2	20.7	18.2	16.1	20.3
Southeast	18.8	12.9	24.6	18.9	16.7	21.1	18.9	16.8	21.0
Western	18.5	13.7	23.3	11.6	10.0	13.3	13.1	11.4	14.7

Note: *p<0.05; **p<0.01; ***p<0.001

Marijuana Attitudes and Perceptions

Table 3 presents attitudes and perceptions about marijuana. More than half of Massachusetts adults, 58.5%, favor the legalization of marijuana. As for risk perceptions, 20.0% of Massachusetts adults perceive marijuana to have no risks, 32.5% perceive it to have slight risks, 26.4% perceive moderate risks, and 21.0% perceive great risks.

We stratified data to examine attitudes and perceptions among Massachusetts adults who had used marijuana in the past 30 days compared with adults who had not. A majority of marijuana users, 96.5%, favor the legalization of marijuana, whereas less than half of non-users, 48.2%, favor marijuana legalization (p<0.001). A greater proportion of marijuana users than non-users perceive marijuana to have no health risks, or slight risks (p<0.001).

Table 3. Marijuana Attitudes and Perceptions of Marijuana Users and Non-Users

	In the past 30 days, did you use marijuana or hashish at least once?								
	Yes: n=439, 21.1% (95% CI 18.6, 23.6)			**No: n=2,583, 78.9%** (95% CI 76.4, 81.4)			**Total: n=3,022**		
	%	**95% CI**		**%**	**95% CI**		**%**	**95% CI**	
Favor marijuana legalization*									
No	3.5	1.1	5.9	51.8	48.9	54.6	41.5	38.9	44.1
Yes	96.5	94.1	98.9	48.2	45.4	51.1	58.5	55.9	61.1
Perceived marijuana risks*									
No risk	47.3	40.4	54.3	12.7	10.4	14.9	20.0	17.6	22.5
Slight risk	44.8	37.9	51.7	29.3	26.7	31.8	32.5	30.0	35.1
Moderate risk	4.7	2.7	6.7	32.3	29.7	34.8	26.4	24.2	28.6
Great risk	3.2	0.8	5.6	25.8	23.3	28.2	21.0	18.9	23.1

Note: *p<0.05; **p<0.01; ***p<0.001

Use of Alcohol and Other Substances

Table 4 presents past 30-day alcohol and other substance use among Massachusetts adults. Among all adults, 69.4% had consumed alcohol in the prior 30 days, and 4.1% had consumed another substance. Other substance use was defined as past 30-day use of any of the following substance types: non-prescribed opioids, cocaine/crack, heroin, non-medical anti-anxiety drugs, and other illicit substances. Prevalence rates were relatively small for each of the other substance categories, i.e., 0.9% for cocaine/crack, 0.1% for heroin, 1.3% for non-medical use of anti-anxiety substances, 1.4% for non-medical use of opioids, and 0.4% for other illegal substances.

We stratified data to examine alcohol and other substance use by adults who had used marijuana in the past 30 days compared with adults who had not. A greater proportion of marijuana users than non-users had used alcohol. Specifically, 82.1% of marijuana users had used alcohol, versus 66.0% of non-users (p<0.001). Also, a greater proportion of marijuana users than non-users had used other substances. Specifically, 9.8% of marijuana users had used other substances, versus 2.6% of non-users (p<0.01). Analysis of each substance type revealed that 3.8% of marijuana users had used non-prescribed opioids, versus 0.8% of non-users (p<0.05), and that similar proportions of adults in each group had past 30-day use of cocaine/crack, heroin, non-medical anti-anxiety drugs, and other illicit substances. Given the low rates of past 30-day use of each of these substances, interpretation of these results should be made with caution.

Table 4. Use of Alcohol and Other Substances of Marijuana Users and Non-Users

	In the past 30 days, did you use marijuana or hashish at least once?								
	Yes: n=439, 21.1% (95% CI 18.6, 23.6)			**No: n=2,583, 78.9%** (95% CI 76.4, 81.4)			**Total: n=3,022**		
	%	**95% CI**		**%**	**95% CI**		**%**	**95% CI**	
Substance use in past 30 days									
Alcohol***	82.1	76.8	87.4	66	63.2	68.8	69.4	66.9	71.9
Cocaine/crack	2.8	0.3	5.2	0.4	0.0	0.9	0.9	0.3	1.6
Heroin	.	.	.	0.1	0.0	0.2	0.1	0.0	0.2
Anti-anxiety, non-medical	1.3	0.0	2.8	1.3	0.4	2.1	1.3	0.5	2.0
Opioids, non-medical*	3.8	1.0	6.6	0.8	0.3	1.2	1.4	0.7	2.1
Other illegal substances	1.5	0.0	3.2	0.1	0.0	0.4	0.4	0.0	0.8
Other substances**	9.8	5.3	14.4	2.6	1.5	3.6	4.1	2.8	5.4

Note: *p<0.05; **p<0.01; ***p<0.001. Other substances" is defined as any past 30-day use of cocaine/crack, heroin, non-medical anti-anxiety substances, non-medical opioids, and other illegal substances.

Marijuana Consumption Patterns, Methods, and Expenditures

Table 5 presents marijuana consumption patterns, methods, and expenditures reported by Massachusetts adults who had used marijuana in the past 30 days. About half (50.6%) of marijuana users consumed it only by smoking, while 42.9% used more than one method of consumption. Fewer marijuana users vaporized or ate marijuana, 2.9% and 2.6%, respectively. Less than 1% only drank or dabbed marijuana, or only used it topically or sublingually.

More than half of Massachusetts adult marijuana users, 56.0%, report using marijuana only for adult non-medical purposes. Adults also use marijuana for medical reasons; 4% only used prescribed marijuana, 11.5% only used non-prescribed marijuana. In other words, 15.5% used either prescribed or not prescribed marijuana for medical reasons. More than one-quarter, 28.5%, reported both adult and medical marijuana use.
Of Massachusetts adult marijuana users, 35.5% spent no money on marijuana in the past month, 31.5% spent between $1 and $80, and 33.0% spent $81 or more.

Table 5. Marijuana Consumption Patterns, Methods, and Expenditures

	Adults who used marijuana in past 30 days (n=439)		
	%	95% CI	
How used marijuana, past 30 days			
Smoke	50.6	43.6	57.5
Vaporize	2.9	1.3	4.4
Eat	2.6	0.6	4.6
Drink	0.3	0.0	0.7
Topical	0.3	0.0	0.6
Sublingual	0.3	0.0	0.7
Dab	0.2	0.0	0.7
More than 1 route of administration	42.9	36.1	49.7
Reasons used marijuana in past 30 days			
Adult (non-medical) only	56.0	49.1	62.9
Medical (prescribed) only	4.0	1.8	6.2
Medical (not prescribed) only	11.5	7.3	15.6
Any medical (prescribed and not prescribed)	15.5	--	--
Both adult and any medical	28.5	22.3	34.8
Amount of money spent on marijuana in past 30 days			
$0	35.5	28.9	42.1
$1-80	31.5	24.8	38.3
$81-800	33.0	26.2	39.7

Correlates of Marijuana Use

Table 6 presents results from the Poisson regression examining socio-demographics and other factors associated with past 30-day marijuana use (defined as a dichotomous variable, yes versus no) by Massachusetts adults. It is important to remember that because the survey used a cross-sectional design, the results shown here reflect factors that are associated with marijuana use and cannot be interpreted as being causally related to marijuana use. We report relative risk (RR) and 95% confidence intervals (CI). Men were more likely than women to use marijuana (RR=1.3; 95% CI: 1.1-1.6). Age is also associated with marijuana use. Compared to adults aged 18 to 20, adults aged 26 to 34 were less likely to use marijuana (RR=0.6; 95% CI: 0.4-0.9), as are those aged 35 to 64 (RR=0.3; 95% CI: 0.2-0.5), and adults aged 65 and older (RR=0.1; 95% CI: 0.1-0.2). Having a graduate degree, compared with having attained a High School education or less, was negatively associated with marijuana use (RR=0.5; 95% CI: 0.4-0.8). Renting a home, compared with owning a home, was positively associated with marijuana use (RR=1.5; 95% CI: 1.1-1.9). Having children in the home was negatively associated with marijuana use (RR=0.8; 95% CI: 0.6-1.0). Compared with living in Boston, living in the Northeast (RR=1.8; 95% CI: 1.2-2.7), Southeast (RR=1.8; 95% CI: 1.1-2.7), and Western (RR=2.0; 95% CI: 1.3, 3.0) regions of the state are each positively associated with marijuana use. Marijuana use is positively associated with past 30-day use of alcohol (RR=1.9; 95% CI: 1.4-2.6) and other substances (RR=1.7; 95% CI: 1.3-2.4). See Table 6.

Table 6. Adjusted Relative Risk of Marijuana Use

	Adjusted Relative Risk	**95% Confidence Interval**	
Male (ref: Female)*	1.3	1.1	1.6
Age (ref: 18-20)			
21-25	0.8	0.5	1.3
26-34*	0.6	0.4	0.9
35-64***	0.3	0.2	0.5
65+***	0.1	0.1	0.2
Race/Ethnicity (ref: White, non-Hispanic)			
Hispanic	1.0	0.7	1.5
Black, non-Hispanic	1.1	0.7	1.7
Asian, non-Hispanic	0.6	0.2	1.2
Other, non-Hispanic	1.4	0.9	2.1
Education (ref: Less than high school)			
College	0.8	0.6	1.1
Graduate degree**	0.5	0.4	0.8
Home ownership (ref: own)			
Rent**	1.5	1.1	1.9
Something else	1.0	0.7	1.6
Children in household (ref: No)*	0.8	0.6	1.0
Region (ref: Boston)			
Metrowest	1.4	0.9	2.1
Northeast**	1.8	1.2	2.7
Southeast*	1.8	1.1	2.7
Central	1.5	0.9	2.3
Western**	2.0	1.3	3.0
Alcohol use, past 30 days (ref: No)***	1.9	1.4	2.6
Other substance use, past 30 days (ref: No)**	1.7	1.3	2.4

Note: *p<0.05; **p<0.01; ***p<0.001. Results are based on weighted, multivariable regression analysis.

Discussion

We found that 21.1% of adults in Massachusetts had used marijuana in the past 30 days. Estimates are substantially higher than those provided by other surveys. For example, as presented in Chapter 1, 5.2% of Massachusetts adults aged 26 or older reported recent use of marijuana in 2006, and 9.2% reported recent use in 2014. In the present study, 18.0% of adults aged 26 or older had used marijuana in the past 30 days. Increases in marijuana prevalence among Massachusetts adults may be attributable to shifts in public opinion regarding marijuana, and in marijuana-related law and public policy.

Men in Massachusetts are more likely than women to use marijuana, as are individuals aged 18 to 20. Marijuana prevalence rates are 25.9% for men and 17.0% for women, 54.4% for those aged 18 to 20 and 49.1% for those aged 21 to 25. Findings regarding the greater likelihood of marijuana use by men and younger adults remained significant in regression analysis which accounts for the effect of other factors on marijuana use. Relationships are more complex between marijuana use and other factors, in particular, race/ethnicity and education.

By race/ethnicity, prevalence of marijuana use is highest among Hispanics, at 27.1%, followed by 25.8% of Blacks, 20.1% of Whites, 10.4% of Asians, and 37.5% of other race/ethnic groups. Among marijuana users living in MA, most are White, 70.8%, and many fewer are Hispanic, 12.0%, Black, 7.1%, other, 6.9%, or Asian, 3.2%. In the regression analysis, which accounted for the effect of other factors, race/ethnicity was not associated with marijuana use, suggesting that the likelihood of using marijuana is similar for each group (compared to Whites), when other factors are accounted for.
As for educational attainment, prevalence data and bivariate analysis indicate that a greater proportion of adults with a High School degree or college education use marijuana than adults with a graduate degree. In regression analysis, which accounts for the effect of other factors on marijuana use, adults with a college education are as likely to use marijuana as those with a high school education or less. In contrast, adults with a graduate degree are less likely to use marijuana that those with a High School education or less. Relationships between marijuana use, educational attainment, and other indicators of economic status are known to be complex and poorly understood. For example, college students face added risks for marijuana use that have been attributed to a diverse set of factors that include: overestimation among college students regarding how often the average student uses drugs (McCabe, 2008); perceptions among college students that drug use during their college years is normative (Cook, Bauermeister, Gordon-Messer & Zimmerman, 2013; Pischke et al., 2012); the expectation among college students that drugs will reduce social anxiety and facilitate the formation of new peer friendships (Buckner, 2013); and greater exposure to drug-using opportunities that exist on college campuses (Arria et al., 2008).

Patterns of marijuana use among college graduates have been attributed to age-graded changes in social roles and associated normative behavior that generally accompany the life transitions that this event signifies (Kandel & Chen, 2000). The present study was not designed to explore these types of relationships, and therefore findings should be interpreted with caution.

By region, residents in the Western area of the state report the highest prevalence rate of past 30-day marijuana use, at 29.8%, with rates in other areas of the Commonwealth ranging from 20.9% to 18.2%. In Poisson regression analysis, compared with living in Boston, living in the Northeast, Southeast, and Western regions of the state are each positively associated with marijuana use. Findings suggest that the public health impacts of marijuana use may not be evenly distributed across the state. Other factors associated with a lower likelihood of marijuana use are home ownership and having children in home. Given the cross-sectional design of the study, we cannot determine the nature of these relationships and therefore these findings should not be interpreted as being causally related.

About 7 out of 10 Massachusetts adults consume alcohol, and 4 out of 100 consume another substance (e.g., non-prescribed opioids, cocaine/crack, heroin, non-medical anti-anxiety drugs, and other illicit substances). Notably, a greater proportion of Massachusetts marijuana users than non-users consume alcohol and other substances, particularly non-prescribed opioids, and use of alcohol and other substances is associated with a greater likelihood of using marijuana. The co-occurring use of marijuana with alcohol and other substances, particularly during adolescence and young adulthood, is well-established (Swift et al., 2012; Tzilos, Reddy, Caviness, Anderson & Stein, 2014).

Just over half of Massachusetts adults favored the legalization of marijuana, with double the proportion of marijuana users than non-users supporting legalization. As there have been dramatic shifts in public opinion regarding marijuana and in marijuana-related law and public policy (Pacula et al., 2005; Pacula, Kilmer, Wagenaar, Chaloupka, & Caulkins, 2014; Pew Research Center, 2014), the incidence and prevalence of both marijuana use and also marijuana use disorders are expected to increase (Budney & Moore, 2002; Hasin et al., 2017; Martins et al., 2016; Volkow, Baler, Compton, & Weiss, 2014). Of those who ever use marijuana, about 21% develop a marijuana use disorder (Caulkins, 2018). However, the proportion of marijuana users who meet disorder criteria is different by age. For example, national prevalence data indicate that in 2016, approximately 7.2 million young adults aged 18 to 25 were current users of marijuana, or 20.8% of young adults, and of these, 1.7 million had a marijuana use disorder in the past year, or 5.0% (SAMHSA, 2017). Expressed another way, these data indicate that about 24% of young adults aged 18 to 25 who use marijuana meet disorder criteria. Longitudinal studies have documented that while marijuana use can extend over many years of the life course, for most individual's problematic marijuana use is generally limited to young adulthood (Chen & Jacobsen, 2012; DeWit, Offord & Wong, 1997; Schulenberg et al., 2005), and only about 9% of marijuana users remain dependent on the substance over the long-term (Hall & Degenhardt, 2009). However, once a marijuana use disorder does develop, it is associated with increased risk of several diseases and poor health outcomes, including impaired respiratory function, cardiovascular disease, adverse effects on adolescent psychosocial development and mental health, and residual cognitive impairment (Hall & Degenhardt, 2013). In the present study, we only examined marijuana use, and we did not include measurement of marijuana use disorders.

More than half of adult marijuana users in Massachusetts report using marijuana only for adult non-medical purposes, but a significant proportion also report using it for medical reasons. At the same time, a greater proportion of marijuana users than non-users perceive marijuana to have no health risks, or only slight risks, and marijuana users are less likely to perceive that marijuana poses moderate or great risks. Marijuana is primarily used for adult use because it induces euphoria, drowsiness, and feelings of relaxation (Inaba & Cohen, 2011). Individuals who use marijuana therapeutically report that it relieves conditions and symptoms such as glaucoma, nausea, AIDS-associated anorexia and wasting syndrome, chronic pain, inflammation, multiple sclerosis, and epilepsy (Volkow, Baler, Compton, & Weiss, 2014). When taken in combination with prescribed medications, however, marijuana may increase the risk of bleeding, change the impact of medications to address blood sugar levels and low blood pressure, interfere with the body's ability to process certain medications, and have other negative impacts. Studies are underway now to better understand the health risks and benefits of marijuana use.

Finally, Accountable Care Organizations and ongoing health care reforms are expected to bring more marijuana users into primary care and other health care settings (Tai et al., 2014; Gordon, Conley & Gordon, 2013). The National Institute on Drug Abuse and other organizations have published evidence-based guidelines on the screening, brief intervention, and treatment of marijuana and other substance use. Also, the proliferation of electronic health records (EHRs) provides the opportunity to track marijuana use, assess its potential interaction with other therapies, and treat it when needed (Fihn et al., 2014; Halamka, 2014; Longhurst, Harrington & Shah, 2014; Weil, 2014). However, given the special regulations that govern addiction healthcare records (e.g., 42 CFR) and reluctance among patients and physicians to report the illicit and stigmatized behaviors that marijuana use once entailed, clinicians may not document marijuana use or refrain from discussing its potential health impacts with patients.

Limitations and Strengths

Findings must be considered within the context of several limitations. The survey response rate was 21.7%. While typical of general population surveys like this one, if there was a response bias on a measure not accounted for by the weighting, generalizability may be limited. For example, findings may be impacted by response bias if adults who used marijuana were more likely to return the survey than adults who do not use marijuana. This could lead to overestimation of the prevalence of marijuana use. The cross-sectional survey design precludes determining the temporal sequencing of experiences and prevents drawing of causal inferences. For this reason, it is appropriate to interpret findings as highlighting those factors that are associated with, but not necessarily causally related to, the outcomes of interest.

Marijuana and other substance use were both self-reported, and not corroborated by testing of biological samples. Social desirability bias can lead to underestimates in survey research, however a unique contribution of this study is that it is the first to be conducted in Massachusetts after legalization of marijuana for adult use. Data was collected in late 2017, nearly one year after marijuana became legal for adult use by, and several years after legalization of medical marijuana in Massachusetts. Reporting of illegal behaviors (e.g. use of illicit drugs; driving under the influence of alcohol or drugs) may be underreported.

Small cell sizes for categories of some variables likely mean that models including them are underpowered. The survey omitted individuals aged 17 or younger and adults living in non-residential settings (e.g., incarcerated settings, group home residents, etc.). Therefore, findings may underrepresent certain groups that may be more likely to use marijuana. We did not explore associations comparing mental health conditions, adulthood trauma, or other known risk factors for marijuana use, whether associations are different among subgroups of adults (moderation), or the processes through which factors are associated with the outcomes of interest (mediation), constituting several areas for future research.

References

Allen, J., & Holder, M. D. (2014). Marijuana use and well-being in university students. *Journal of Happiness Studies*, *15*(2), 301–321. https://doi.org/10.1007/s10902-013-9423-1.

Arria, A. M., Caldeira, K. M., O'Grady, K. E., Vincent, K. B., Fitzelle, D. B., Johnson, E. P., & Wish, E. D. (2008). Drug exposure opportunities and use patterns among college students: results of a longitudinal prospective cohort study. *Subst Abus, 29*(4), 19-38. doi: 10.1080/08897070802418451.

Bachhuber MA, Saloner B, Cunningham CO, Barry CL. (2014) Medical cannabis laws and opioid analgesic overdose mortality in the United States, 1999-2010. *JAMA Intern Med,* Oct;174(10):1668-73.

Buckner, J. D. (2013). College cannabis use: the unique roles of social norms, motives, and expectancies. *J Stud Alcohol Drugs, 74*(5), 720-726.

Budney, A.J., Moore, B.A. (2002). Development and consequences of cannabis dependence. *Journal of Clinical Pharmacology*, 42(11 Supplement): 28S-33S.

Cambron, C., Guttmannova, K., & Fleming, C. B. (2017). State and national contexts in evaluating cannabis laws: A case study of Washington State. *Journal of Drug Issues*, 47(1), 74–90. https://doi.org/10.1177/0022042616678607.

Caulkins, J.P. (2018). The real dangers of marijuana. *National Affairs,* 35. Retrieved from https://www.nationalaffairs.com/publications/detail/the-real-dangers-of-marijuana.

Chen, P., & Jacobson, K. C. (2012). Developmental trajectories of substance use from early adolescence to young adulthood: gender and racial/ethnic differences. *J Adolesc Health, 50*(2), 154-163. doi: 10.1016/j.jadohealth.2011.05.013.

Cook, S. H., Bauermeister, J. A., Gordon-Messer, D., & Zimmerman, M. A. (2013). Online network influences on emerging adults' alcohol and drug use. *J Youth Adolesc, 42*(11), 1674-1686. doi: 10.1007/s10964-012-9869-1.

DeWit, D. J., Offord, D. R., & Wong, M. (1997). Patterns of onset and cessation of drug use over the early part of the life course. *Health Educ Behav, 24*(6), 746-758.

Fihn, S.D., Francis, J., Clancy, C., Nielson, C., Nelson, K., Rumsfeld, J., Cullen, T., Bates, J., Graham, G.L. (2014). Insights from advanced analytics at the Veterans Health Administration. *Health Affairs (Millwood)*, 33(7): 1203-1211.

Gordon, A.J., Conley, J.W., Gordon, J.M. (2013). Medical consequences of marijuana use: a review of current literature. *Current Psychology Reports*, 15(12): 419.

Halamka, J. (2007, November 12). Data, information, knowledge, and wisdom. [Web log post]. Retrieved from http://geekdoctor.blogspot.com/2007/11/data-information-knowledge-and-wisdom.html.

Hall, W., Degenhardt, L. (2014). The adverse health effects of chronic cannabis use. *Drug Testing and Analysis*, 6(1-2): 39-45.

Hall, W. & Degenhardt, L. (2009). Adverse health effects of non-medical cannabis use. *Lancet*, 374, 1383–1391.

Hall, W. & Kozlowski, L.T. (2015). The diverging trajectories of cannabis and tobacco policies in the United States: reasons and possible implications. *Addiction*, 313(3), 241–242. https://doi.org/10.1038/nbt.3121.ChIP-nexus.

Hasin DS, Sarvet AL, Cerdá M, Keyes KM, Stohl M, Galea S, Wall MM. (2017) US Adult

Illicit Cannabis Use, Cannabis Use Disorder, and Medical Marijuana Laws: 1991-1992 to 2012-2013. *JAMA Psychiatry,* Jun 1;74(6):579-588.
Inaba DS & Cohen WE. Uppers, downers, all arounders. Seventh Edition. CNS Productions, Inc. Medford OR.
Kandel, D. B., & Chen, K. (2000). Types of marijuana users by longitudinal course. *J Stud Alcohol, 61*(3), 367-378.
Keyes, K. M., Wall, M., Cerdá, M., Schulenberg, J., O'Malley, P. M., Galea, S., Hasin, D.S. (2016). How does state marijuana policy affect US youth? Medical marijuana laws, marijuana use and perceived harmfulness: 1991–2014. *Addiction*, *111*(12), 2187–2195. https://doi.org/10.1111/add.13523.
Longhurst, C.A., Harrington, R.A., Shah, N.H. (2014). A 'green button' for using aggregate patient data at the point of care. *Health Affairs (Millwood)*, 33(7): 1229-1235.
Martins SS, Mauro CM, Santaella-Tenorio J, Kim JH, Cerda M, Keyes KM, Hasin DS, Galea S, Wall M. (2016). State-level medical marijuana laws, marijuana use and perceived availability of marijuana among the general U.S. population. *Drug Alcohol Depend*. Dec 1; 169:26-32.
McCabe, S. E. (2008). Misperceptions of non-medical prescription drug use: a web survey of college students. *Addict Behav, 33*(5), 713-724. doi: 10.1016/j.addbeh.2007.12.008.
Monte, A. A., Zane, R. D., & Heard, K. J. (2015). The implications of marijuana legalization in Colorado. *JAMA*, *313*(3), 241–242. https://doi.org/10.1038/nbt.3121.ChIP-nexus.
Olfson M, Wall MM, Liu SM, Blanco C. (2018). Cannabis Use and Risk of Prescription Opioid Use Disorder in the United States. *Am J Psychiatry*. Jan 1;175(1):47-53.
Pacula, R.L., Kilmer, B., Wagenaar, A.C., Chaloupka, F.J., Caulkins, J.P. (2014). Developing public health regulations for marijuana: lessons from alcohol and tobacco. *American Journal of Public Health*, 104(6): 1021-1028.
Pacula, R.L., MacCoun, R., Reuter, P., Chriqui, J., Kilmer, B., Harris, K., Paoli, L., Schäfer, C. (2005). What does it mean to decriminalize marijuana? A cross-national empirical examination. *Advances in Health Economics and Health Services Research*, 16: 347-369.
Pew Research Center. (2014). America's new drug policy landscape: Two-thirds favor treatment, not jail, for use of heroin, cocaine.
Pischke, C. R., Zeeb, H., van Hal, G., Vriesacker, B., McAlaney, J., Bewick, B. M., . . . Mikolajczyk, R. T. (2012). A feasibility trial to examine the social norms approach for the prevention and reduction of licit and illicit drug use in European University and college students. *BMC Public Health, 12*, 882. doi: 10.1186/1471-2458-12-882.
Powell D, Pacula RL, Jacobson M. (2018). Do medical marijuana laws reduce addictions and deaths related to pain killers? *J Health Econ,* Jan 30;58:29-42.
Schulenberg JE, Merline AC, Johnston LD, O'Malley PM, Bachman JG, Laetz VB. (2005). Trajectories of Marijuana Use During the Transition to Adulthood: The Big Picture Based on National Panel Data. *J Drug Issues,* 35(2):255-279.
Substance Abuse and Mental Health Services Administration. (2017). Key substance use and mental health indicators in the United States: Results from the 2016

National Survey on Drug Use and Health (HHS Publication No. SMA 17-5044, NSDUH Series H-52). Rockville, MD: Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration. Retrieved from https://www.samhsa.gov/data/.

Swift, A. (2013). For first time Americans favor legalizing marijuana. Retrieved from www.gallup.com.

Swift, W., Coffey, C., Degenhardt, L., Carlin, J. B., Romaniuk, H., & Patton, G. C. (2012). Cannabis and progression to other substance use in young adults: findings from a 13-year prospective population-based study. *J Epidemiol Community Health, 66*(7), e26. doi: 10.1136/jech.2010.129056.

Tai, B., Hu, L., Ghitza, U.E., Sparenborg, S., Van Veldhuisen, P., Lindblad, R. (2014). Patient registries for substance use disorders. *Substance Abuse and Rehabilitation*, 5: 81-86.

Tzilos, G. K., Reddy, M. K., Caviness, C. M., Anderson, B. J., & Stein, M. D. (2014). Getting higher: co-occurring drug use among marijuana-using emerging adults. *J Addict Dis, 33*(3), 202-209. doi: 10.1080/10550887.2014.950024.

Volkow, N.D., Baler, R.D., Compton, W.M., Weiss, S.R.B. (2014). Adverse Health Effects of Marijuana Use. *The New England Journal of Medicine*, 370: 2219-2227.

Vyas MB, LeBaron VT, Gilson AM. (2018). The use of cannabis in response to the opioid crisis: A review of the literature. *Nurs Outlook,* Jan - Feb;66(1):56-65.

Weil, A.R. (2014). Big data in health: a new era for research and patient care. *Health Affairs (Millwood)*, 33(7): 1110.

Zou, G. (2004). A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol, 159*(7), 702-706.

Chapter 3: Use and Perceptions of Marijuana among Adult Medical Use of Marijuana Patients in Massachusetts

Introduction

This report provides data and analysis on the 2018 Medical Use of Marijuana Patient Survey, a component of the Massachusetts Department of Public Health 2018 Marijuana Baseline Study. The aim of this survey is to better understand the patterns of marijuana use, perceptions, and behaviors among medical use of marijuana patients in Massachusetts. Massachusetts Department of Public Health contracted with JSI Research & Training Institute in April 2018 to administer a survey among participants of the Massachusetts Medical Use of Marijuana Program. 42,796 participants of the Massachusetts Medical Use of Marijuana Program were invited through email to take the survey using a computer, smartphone, or tablet.

Methods

Data collection efforts were conducted in April 2018 by JSI Research & Training Institute in conjunction with Massachusetts Department of Public Health. All registered participants of the Massachusetts Medical Use of Marijuana Program were invited to complete the survey via an emailed link to Survey Gizmo. The survey incorporated 81 items covering topics such as demographics, marijuana and marijuana product use, methods of marijuana administration, perceptions of medical use of marijuana, driving and other issues related to marijuana use, alcohol consumption, non-medical use of prescription drugs and other substances, and combination substance use. Respondents were sent 2 reminder emails and given the option at the end of the survey to enter a lottery drawing of $500, $250, or $100.

The analyses look both at individual item response summaries as well as investigating differences between gender (male vs. female), age (≤50 years old vs. >50 years old), and education level (<Bachelor’s (4-year college) degree vs. ≥Bachelor’s degree) through cross-tabulation comparisons. Chi-square tests for equality of proportions were run to detect significant differences in item response distribution across groups. Exact significance tests were used to test equality of proportions in cases where response categories were too small for reliable chi-square testing. In cases where mean statistics are presented, independent t-tests were run to detect significant differences between comparison groups. Highly statistically significant results are highlighted in the summary text throughout this report, and all tables present item response frequency, percentages, and results of statistical testing.
Appendix B contains all survey questions administered as well as guiding logic used to prompt or restrict respondents to relevant next questions based on their answers to previous items.

Results

Response Rate

Table 1 shows demographic characteristics of the overall survey sample compared to all eligible survey participants. All adult registered medical use of marijuana patients in the Massachusetts Medical Use of Marijuana Program were eligible for participation in the 2018 Medical Use of Marijuana Patient Survey (N=42,796). 6934 of these patients responded to the 2018 Medical Use of Marijuana Patient Survey, for a response rate of nearly 16%. There were no noticeable differences between 2018 survey respondent distributions and the full eligible population across gender, age, and county, suggesting that respondent population demographics are comparable to the overall eligible population of medical use of marijuana patients in Massachusetts.

Table 1. DPH Patient Survey Response Rate and Comparison of Sample Population

	Full Eligible Population (N=42,796)		**2018 Survey Respondents** (N=6934)	
Response Rate				**15.93%**
Gender	**N=42796**	**%**	**N=6818**	**%**
Male	24349	(56.90)	3723	(54.61)
Female	18387	(42.96)	3056	(44.82)
Other / choose not to answer	60	(0.14)	39	(0.57)
Age (in years)	**N=42796**	**%**	**N=6772**	**%**
18 to 25	3471	(8.11)	477	(7.04)
26 to 35	8695	(20.32)	1256	(18.55)
36 to 50	11857	(27.71)	1851	(27.33)
51 to 64	12141	(28.37)	2100	(31.01)
65 or older	6632	(15.50)	1088	(16.07)
County	**N=42796**	**%**	**N=6864**	**%**
Barnstable	1567	(3.66)	245	(3.57)
Berkshire	1052	(2.46)	210	(3.06)
Bristol	3155	(7.37)	460	(6.70)
Dukes	95	(0.22)	23	(0.34)
Essex	4950	(11.57)	743	(10.82)
Franklin	670	(1.57)	156	(2.27)
Hampden	2974	(6.95)	501	(7.30)
Hampshire	1962	(4.58)	392	(5.71)
Middlesex	9969	(23.29)	1536	(22.38)
Nantucket	40	(0.09)	6	(0.09)
Norfolk	4808	(11.23)	639	(9.31)
Plymouth	3686	(8.61)	533	(7.77)
Suffolk	3936	(9.20)	658	(9.59)
Worcester	3876	(9.06)	606	(8.87)
Not provided	56	(0.13)	223	(0.02)

Respondent Demographics

Approximately equal proportions of all respondents were male compared to female (55% vs. 45%) or under 51 years old (53% vs. 47%). A majority of respondents were Non-Hispanic White (87%), followed by Hispanic (5%), and Non-Hispanic Black or African American (3%). Less than 3% of respondents identified as more than one race, or other (Asian, Native Hawaiian, Pacific Islander, American Indian, Alaska Native, or other). 98% of all respondents reported their highest level of education as at least high school graduation or GED, while over 50% reported receiving a Bachelor's degree or higher. Less than 10% reported an annual household income below $15,000, with the majority reporting over $40,000. Less than 1% of women were currently pregnant or breastfeeding.

Table 2A shows results of significance tests comparing demographic characteristics by gender. A significantly larger proportion of female than male respondents reported their highest education as a professional degree beyond a Bachelor's degree (27% vs. 22%). Female respondents reported annual household incomes between $15,000 and $75,000 compared to males (46% vs. 38%), while a larger proportion of male respondents than female reported annual household incomes above $75,000 (53% vs. 44%).

Table 2B shows results of significance tests comparing demographic characteristics by age group. The racial distribution of respondents under the age of 51 was significantly more diverse than respondents over the age of 50, as exhibited by the proportion of non-Hispanic White respondents (83% vs. 93%). Most notably, a larger proportion of Hispanic respondents were under age 51 than over 50. A larger proportion of respondents over the age of 50 than under had professional degrees beyond a Bachelor's degree (29% vs. 20%). Older respondents reported annual household income earnings above $100,000 at a higher rate than younger respondents (38% vs. 34%).

Table 2C shows results of significance tests comparing demographic characteristics by educational attainment. A larger proportion of respondents with at least a Bachelor's degree than respondents without a degree were aged 65 years or older (20% vs. 12%) or between 26 to 35 years old (20% vs. 17%), while a larger proportion of respondents without a Bachelor's degree were aged between 18 and 25 (10% vs. 4%) and 51 to 64 (33% vs. 29%). A larger proportion of respondents with at least a Bachelor's degree identified as non-Hispanic White compared to respondents with an educational attainment below a Bachelor's degree (90% vs. 84%). Respondents with at least a Bachelor's degree also reported annual household incomes above $75,000 at higher rates than participants without a Bachelor's degree (63% vs. 33%).

Table 2A: DPH Patient Survey Characteristics of Respondents by Gender

	Total N %	Gender		
		Male (N=3732)	**Female** (N=3056)	**p-value**
Gender	6818			no test
Male	3723			
	54.61			
Female	3056			
	44.82			
Other / choose not to answer	39			
	0.57			
Age (in years)	6772			**
18 to 25	477	244	214	
	7.04	6.66	7.13	
26 to 35	1256	668	543	
	18.55	18.23	18.10	
36 to 50	1851	1012	819	
	27.33	27.62	27.30	
51 to 64	2100	1091	991	
	31.01	29.78	33.03	
65 or older	1088	649	433	
	16.07	17.71	14.43	
Race/Ethnicity	6672			ns
White or Caucasian, non-Hispanic	5834	3138	2623	
	87.44	87.39	87.70	
Black or African-American, non-Hispanic	188	102	83	
	2.82	2.84	2.77	
Asian, non-Hispanic	52	29	22	
	0.78	0.81	0.74	
Native Hawaiian, Pacific Islander, American Indian or Alaska Native, non-Hispanic	14	8	6	
	0.21	0.22	0.20	
More than one race, non-Hispanic	171	79	89	
	2.56	2.20	2.98	
Hispanic	323	183	133	
	4.84	5.10	4.45	
Other	90	52	35	
	1.35	1.45	1.17	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 2A. DPH Patient Survey Characteristics of Respondents by Gender

	Total N %	Gender		
		Male (N=3732)	Female (N=3056)	p-value
Highest level of education completed	6877			****
Less than high school	131	91	37	
	1.90	2.45	1.21	
High school or GED	816	483	320	
	11.87	12.98	10.50	
Some college credit, less than Bachelor's degree	2335	1233	1066	
	33.95	33.14	34.96	
cBachelor's degree	1930	1097	804	
	28.06	29.48	26.37	
Professional degree beyond a Bachelor's degree	1665	817	822	
	24.21	21.96	26.96	
Annual household income (all sources)	6279			****
Less than $15,000	578	285	275	
	9.21	8.39	9.85	
$15,000 to $39,999	1147	559	564	
	18.27	16.46	20.19	
$40,000 to $74,999	1475	743	713	
	23.49	21.88	25.53	
$75,000 to $99,999	847	467	369	
	13.49	13.75	13.21	
$100,000 or more	2232	1342	872	
	35.55	39.52	31.22	
Currently Pregnant	3070			no test
No	3054			
	99.48			
Yes	16			
	0.52			
Currently Breastfeeding	3061			no test
No	3058			
	99.90			
Yes	3			
	0.10			

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 2B: DPH Patient Survey Characteristics of Respondents by Age Group

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
Gender	6818			****
Male	3723	1924	1740	
	54.61	54.01	54.79	
Female	3056	1576	1424	
	44.82	44.24	44.84	
Other / choose not to answer	39	37	2	
	0.57	1.04	0.06	
Age (in years)	6772			no test
18 to 25	477			
	7.04			
26 to 35	1256			
	18.55			
36 to 50	1851			
	27.33			
51 to 64	2100			
	31.01			
65 or older	1088			
	16.07			
Race/Ethnicity	6672			****
White or Caucasian, non-Hispanic	5834	2860	2868	
	87.44	82.66	92.52	
Black or African-American, non-Hispanic	188	124	64	
	2.82	3.58	2.06	
Asian, non-Hispanic	52	44	8	
	0.78	1.27	0.26	
Native Hawaiian, Pacific Islander, American Indian or Alaska Native, non-Hispanic	14	5	9	
	0.21	0.14	0.29	
More than one race, non-Hispanic	171	112	57	
	2.56	3.24	1.84	
Hispanic	323	265	55	
	4.84	7.66	1.77	
Other	90	50	39	
	1.35	1.45	1.26	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 2B: DPH Patient Survey Characteristics of Respondents by Age Group

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
Highest Level of Education Completed	6877			****
Less than high school	131	81	45	
	1.90	2.26	1.41	
High school or GED	816	434	367	
	11.87	12.13	11.53	
Some college credit, less than Bachelor's degree	2335	1235	1052	
	33.95	34.53	33.05	
Bachelor's degree	1930	1108	797	
	28.06	30.98	25.04	
Professional degree beyond a Bachelor's degree	1665	719	922	
	24.21	20.10	28.97	
Annual Household Income (all sources)	6279			****
Less than $15,000	578	371	200	
	9.21	11.23	6.98	
$15,000 to $39,999	1147	619	504	
	18.27	18.73	17.58	
$40,000 to $74,999	1475	766	677	
	23.49	23.18	23.61	
$75,000 to $99,999	847	437	399	
	13.49	13.22	13.92	
$100,000 or more	2232	1112	1087	
	35.55	33.65	37.91	
Currently Pregnant	3070			***
No	3054	1581	1417	
	99.48	99.06	99.93	
Yes	16	15	1	
	0.52	0.94	0.07	
Currently Breastfeeding	3061			ns
No	3058	1589	1413	
	99.90	99.81	100.00	
Yes	3	3	0	
	0.10	0.19	0.00	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 2C: DPH Patient Survey Characteristics of Respondents by Education

	Total N %	Education < Bachelor's (N=3282)	≥ Bachelor's (N=3595)	p-value
Gender	6818			ns
Male	3723	1807	1914	
	54.61	55.70	53.70	
Female	3056	1423	1626	
	44.82	43.87	45.62	
Other / choose not to answer	39	14	24	
	0.57	0.43	0.67	
Age (in years)	6772			****
18 to 25	477	320	157	
	7.04	9.96	4.43	
26 to 35	1256	533	721	
	18.55	16.58	20.33	
36 to 50	1851	897	949	
	27.33	27.91	26.76	
51 to 64	2100	1076	1021	
	31.01	33.48	28.79	
65 or older	1088	388	698	
	16.07	12.07	19.68	
Race/Ethnicity	6672			****
White or Caucasian, non-Hispanic	5834	2693	3134	
	87.44	84.39	90.26	
Black or African-American, non-Hispanic	188	119	68	
	2.82	3.73	1.96	
Asian, non-Hispanic	52	17	35	
	0.78	0.53	1.01	
Native Hawaiian, Pacific Islander, American Indian or Alaska Native, non-Hispanic	14	13	1	
	0.21	0.41	0.03	
More than one race, non-Hispanic	171	91	80	
	2.56	2.85	2.30	
Hispanic	323	209	113	
	4.84	6.55	3.25	
Other	90	49	41	
	1.35	1.54	1.18	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 2C: DPH Patient Survey Characteristics of Respondents by Education

	Total N %	Education		
		< Bachelor's (N=3282)	**≥ Bachelor's** (N=3595)	**p-value**
Highest level of education completed	6877			no test
Less than high school	131 1.90			
High school or GED	816 11.87			
Some college credit, less than Bachelor's degree	2335 33.95			
Bachelor's degree	1930 28.06			
Professional degree beyond a Bachelor's degree	1665 24.21			
Annual household income (all sources)	6279			****
Less than $15,000	578 9.21	436 14.65	141 4.28	
$15,000 to $39,999	1147 18.27	777 26.11	368 11.18	
$40,000 to $74,999	1475 23.49	779 26.18	694 21.08	
$75,000 to $99,999	847 13.49	344 11.56	500 15.18	
$100,000 or more	2232 35.55	640 21.51	1590 48.28	
Currently Pregnant	3070			ns
No	3054 99.48	1420 99.58	1626 99.39	
Yes	16 0.52	6 0.42	10 0.61	
Currently Breastfeeding	3061			ns
No	3058 99.90	1415 99.86	1636 99.94	
Yes	3 0.10	2 0.14	1 0.06	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

Marijuana and Marijuana Product Use

Table 3A, 3B, and 3C show results of survey responses pertaining to marijuana and marijuana product use, with comparisons by gender, age group, and educational attainment, respectively. All survey respondents were asked to report on the number of days in the past 30 days that they used marijuana or marijuana products. On average, respondents reported marijuana use for 23.5 days out of 30. Over 60% of respondents reported marijuana use for over 20 out of 30 days, while approximately 8% reported no use. A slightly higher rate of respondents under the age of 51 reported at least 11 days of use compared to respondents over age 50 (82% vs. 76%). A larger proportion of respondents without a Bachelor's degree than respondents with a Bachelor's degree reported use for over 20 out of 30 days (65% vs. 56%).

Respondents who indicated having used marijuana or marijuana products at least once in the past 30 days were asked to report their total monthly expenditures on marijuana and marijuana products. Almost 40% of these respondents reported spending at least $201 on marijuana or marijuana products in the past 30 days, while only 10% reported spending nothing. On average, male respondents reported spending approximately $20 more than females, with a larger proportion of males than females spending at least $151 (56% vs. 51%). Respondents under age 51 reported spending an average of $82 more than older respondents, with a larger proportion of younger respondents than older spending at least $151 (60% vs. 47%). Respondents without a Bachelor's degree spent approximately $71 more than respondents with a Bachelor's degree, with a larger proportion of respondents without a Bachelor's spending at least $151 (61% vs. 48%).

All survey respondents were asked to indicate the purpose of their marijuana use in the past 30 days. 93% of respondents reported medical use of marijuana certified by a medical practitioner, 6% reported medical use not certified by a medical practitioner, and 17% of respondents reported recreational use of marijuana. Respondents younger than 51 years old reported higher rates of recreational use than older respondents (20% vs, 14%). Respondents with a Bachelor's degree reported higher rates of recreational use than respondents without a Bachelor's degree (20% vs. 14%).

Table 3A: DPH Patient Survey Marijuana and Marijuana Products by Gender

	Total N %	Gender		
		Male (N=3732)	Female (N=3056)	p-value
Number of days in past 30 days using marijuana (Mean; Std.)	23.53 8.58	23.78 8.36	23.20 8.86	**
Number of days in past 30 days using marijuana	6640			*
0 days	529 7.97	278 7.78	237 8.01	
1-5 days	370 5.57	168 4.70	196 6.63	
6-10 days	495 7.45	260 7.28	230 7.78	
11-20 days	1223 18.42	662 18.54	546 18.46	
21-30 days	4023 60.59	2203 61.69	1748 59.11	
Money spent on marijuana in past 30 days (Mean; Std.) †	$245.59 313.61	$255.06 286.36	$235.00 346.64	*
Total money spent on marijuana / products in past 30 days	4798			****
$0	496 10.34	226 8.65	263 12.43	
$1 - $50	348 7.25	190 7.27	149 7.04	
$51 to $100	809 16.86	450 17.21	346 16.36	
$101 to $150	571 11.90	287 10.98	278 13.14	
$151 to $200	687 14.32	383 14.65	294 13.90	
$201 or more	1887 39.33	1078 41.24	785 37.12	
Purpose of marijuana use †‡				
Recreational (non-medical, e.g., to get high) only	1038 17.00	585 17.79	428 15.74	*
Medical use NOT certified by a qualified practitioner only	380 6.22	238 7.24	134 4.93	***
Medical use certified by a qualified practitioner only	5690 93.2	3029 92.09	2567 94.41	***

† *Among respondents indicating use of marijuana or marijuana products at least once in past 30 days (N=6111)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 3B: DPH Patient Survey Marijuana and Marijuana Product Use by Age Group

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
Number of Days in Past 30 Days Using Marijuana (Mean; Std.)	23.53 8.58	23.93 8.27	23.08 8.89	***
Number of days in past 30 days using marijuana	6640			****
0 days	529 7.97	243 7.01	268 8.76	
1-5 days	370 5.57	171 4.93	191 6.24	
6-10 days	495 7.45	221 6.37	266 8.69	
11-20 days	1223 18.42	664 19.15	546 17.84	
21-30 days	4023 60.59	2168 62.53	1790 58.48	
Money Spent on Marijuana in Past 30 Days (Mean; Std.) †	$245.59 313.61	$285.14 379.04	$203.03 216.65	****
Total money spent on marijuana / products in past 30 days	4798			****
$0	496 10.34	192 7.75	293 13.04	
$1 - $50	348 7.25	145 5.86	196 8.72	
$51 to $100	809 16.86	385 15.55	412 18.34	
$101 to $150	571 11.90	269 10.86	297 13.22	
$151 to $200	687 14.32	368 14.86	310 13.80	
$201 or more	1887 39.33	1117 45.11	739 32.89	
Purpose of Marijuana Use †‡				
Recreational (non-medical, e.g., to get high) only	1038 17.00	651 20.20	381 13.66	****
Medical use NOT certified by a qualified practitioner only	380 6.22	172 5.34	203 7.28	*
Medical use certified by a qualified practitioner only	5690 93.2	3024 93.85	2578 92.40	**

† *Among respondents indicating use of marijuana or marijuana products at least once in past 30 days (N=6111)*

‡ *Percentages sum to more than 100% because respondents could choose more than one option*

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 3C: DPH Patient Survey Marijuana and Marijuana Products Use by Education

	Total N %	Education < Bachelor's (N=3282)	≥ Bachelor's (N=3595)	p-value
Number of days in past 30 days using marijuana (Mean; Std.)	23.53 8.58	24.82 7.94	22.40 8.96	****
Number of days in past 30 days using marijuana	6640			****
0 days	529 7.97	286 9.06	242 6.98	
1-5 days	370 5.57	122 3.86	245 7.07	
6-10 days	495 7.45	180 5.70	314 9.06	
11-20 days	1223 18.42	507 16.06	713 20.58	
21-30 days	4023 60.59	2062 65.32	1951 56.31	
Money spent on marijuana in past 30 days (Mean; Std.) †	$245.59 313.61	$285.18 379.25	$213.81 243.93	****
Total money spent on marijuana / products in past 30 days	4798			****
$0	496 10.34	167 7.79	327 12.38	
$1 - $50	348 7.25	129 6.01	218 8.25	
$51 to $100	809 16.86	315 14.69	491 18.59	
$101 to $150	571 11.90	236 11.00	334 12.65	
$151 to $200	687 14.32	299 13.94	386 14.62	
$201 or more	1887 39.33	999 46.57	885 33.51	
Purpose of marijuana use †‡				
Recreational (non-medical, e.g., to get high) only	1038 17.00	402 14.01	633 19.66	****
Medical use NOT certified by a qualified practitioner only	380 6.22	186 6.48	194 6.02	ns
Medical use certified by a qualified practitioner only	5690 93.2	2673 93.17	3000 93.17	ns

† *Among respondents indicating use of marijuana or marijuana products at least once in past 30 days (N=6111)*

‡ *Percentages sum to more than 100% because respondents could choose more than one option*

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Medical Conditions for Marijuana and Marijuana Product Use

Tables 4A, 4B, and 4C summarize results of survey responses pertaining to medical conditions for which marijuana and marijuana products were used, with comparisons by gender, age group, and educational attainment, respectively. Respondents who did not use marijuana or marijuana products for medical use in the past 30 days (whether certified or uncertified) were asked to indicate all medical conditions for which they used marijuana or marijuana products. Note that percentages in *Tables 4A, 4B, and 4C* add to more than 100% because of multiple conditions being treated at the same time.

The most common medical condition for which respondents indicated marijuana use was anxiety (60%), followed by chronic pain (46%), insomnia (43%), depression (42%), and stress (41%). Respondents also reported treating arthritis, headaches/migraines, muscle spasms, PTSD, and nausea at rates between 16 and 26%.

A significantly larger proportion of female respondents than male reported using marijuana or marijuana products to treat anxiety, arthritis, bowel distress, depression, fibromyalgia, headaches/migraines, multiple sclerosis, nausea, osteoarthritis, PTSD, vomiting, and "other". A larger proportion of male respondents than female reported using marijuana or marijuana products to treat ADHD, alcohol dependency, diabetes, HIV/AIDS, and sleep apnea.

A larger proportion of respondents 51 years or older reported using marijuana or marijuana products to treat arthritis, cancer, chronic pain, diabetes, glaucoma, HIV/AIDS, hypertension, neuropathy, and osteoarthritis. A larger proportion of respondents under 51 years old reported using marijuana or marijuana products to treat ADHD, anxiety, bipolar disorder, bowel distress, depression, headaches/migraines, insomnia, loss of appetite, nausea, OCD, PTSD, stress, and vomiting.

Respondents with a Bachelor's degree did not report using marijuana or marijuana products to treat any of the medical conditions at higher rates than respondents without a Bachelor's degree. Respondents without a Bachelor's degree reported using marijuana or marijuana products at higher rates than respondents with a Bachelor's degree to treat ADHD, anxiety, arthritis, bipolar disorder, carpal tunnel, chronic pain, depression, diabetes, fibromyalgia, headaches/migraines, loss of appetite, muscle spasms, nausea, OCD, opioid use, PTSD, seizures, sleep apnea, and stress.

Table 4A: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Gender

	Total	Gender		
	N %	**Male** (N=3293)	**Female** (N=2720)	**p-value**
Marijuana used for medical purposes	6111			*
No	195	122	70	
	3.19	3.70	2.57	
Yes	5916	3171	2650	
	96.81	96.30	97.43	
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
ADHD	711	424	260	****
	12.02	13.37	9.81	
Alcohol Dependency	164	120	42	****
	2.77	3.78	1.58	
Anxiety	3559	1773	1719	****
	60.16	55.91	64.87	
Arthritis	1563	784	759	***
	26.42	24.72	28.64	
Asthma	190	83	101	**
	3.21	2.62	3.81	
Bipolar Disorder	336	167	162	ns
	5.68	5.27	6.11	
Bowel Distress	562	232	318	****
	9.50	7.32	12.00	
Cancer	331	186	141	ns
	5.59	5.87	5.32	
Carpal Tunnel	214	101	111	*
	3.62	3.19	4.19	
Chronic Pain	2749	1456	1247	ns
	46.47	45.92	47.06	
Crohn's Disease	159	80	78	ns
	2.69	2.52	2.94	
Depression	2463	1213	1195	****
	41.63	38.25	45.09	
Diabetes	216	160	55	****
	3.65	5.05	2.08	
Fibromyalgia	444	76	359	****
	7.51	2.40	13.55	
Glaucoma	143	91	52	*
	2.42	2.87	1.96	

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 4A: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Gender

	Total N %	Gender Male (N=3293)	Female (N=2720)	p-value
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
Headaches/Migraines	1185 20.03	464 14.63	693 26.15	****
Hepatitis C	56 0.95	41 1.29	14 0.53	**
HIV/AIDS	43 0.73	38 1.20	5 0.19	****
Huntington's Disease	2 0.03	1 0.03	1 0.04	ns
Hypertension	318 5.38	201 6.34	111 4.19	***
Insomnia	2524 42.66	1326 41.82	1152 43.47	ns
Loss of Appetite	744 12.58	396 12.49	323 12.19	ns
Multiple Sclerosis	140 2.37	45 1.42	94 3.55	****
Muscle Spasms	1050 17.75	516 16.27	518 19.55	**
Muscular Dystrophy	15 0.25	11 0.35	3 0.11	ns
Nausea	955 16.14	381 12.02	550 20.75	****
Neuropathy	611 10.33	287 9.05	313 11.81	***
OCD	276 4.67	119 3.75	152 5.74	***
Opioid Use	133 2.25	92 2.90	38 1.43	***
Osteoarthritis	466 7.88	183 5.77	280 10.57	****
PTSD	1005 16.99	464 14.63	512 19.32	****
Schizophrenia	17 0.29	13 0.41	2 0.08	*

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued)Table 4A: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Gender

	Total	Gender		
	N **%**	**Male** (N=3293)	**Female** (N=2720)	**p-value**
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
Seizures	114 1.93	60 1.89	52 1.96	ns
Skin Conditions	149 2.52	60 1.89	84 3.17	**
Sleep Apnea	536 9.06	371 11.70	155 5.85	****
Stress	2408 40.70	1259 39.70	1095 41.32	ns
Tourette's Syndrome	18 0.30	16 0.50	2 0.08	**
Tremors	126 2.13	67 2.11	56 2.11	ns
Vomiting	224 3.79	88 2.78	129 4.87	****
Wasting	31 0.52	18 0.57	12 0.45	ns
Weight Loss	243 4.11	128 4.04	109 4.11	ns
Other	779 13.17	360 11.35	406 15.32	****

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 4B: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Age Group

	Total	Age Group		
	N %	≤ 50 years (N=3224)	≥ 51 years (N=2793)	p-value
Marijuana used for medical purposes	6111			ns
No	195	114	78	
	3.19	3.54	2.79	
Yes	5916	3110	2715	
	96.81	96.46	97.21	
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
ADHD	711	555	153	****
	12.02	17.85	5.64	
Alcohol Dependency	164	110	54	***
	2.77	3.54	1.99	
Anxiety	3559	2269	1243	****
	60.16	72.96	45.78	
Arthritis	1563	481	1053	****
	26.42	15.47	38.78	
Asthma	190	98	87	ns
	3.21	3.15	3.20	
Bipolar Disorder	336	268	64	****
	5.68	8.62	2.36	
Bowel Distress	562	347	207	****
	9.50	11.16	7.62	
Cancer	331	77	242	****
	5.59	2.48	8.91	
Carpal Tunnel	214	110	99	ns
	3.62	3.54	3.65	
Chronic Pain	2749	1293	1412	****
	46.47	41.58	52.01	
Crohn's Disease	159	96	58	*
	2.69	3.09	2.14	
Depression	2463	1611	823	****
	41.63	51.80	30.31	
Diabetes	216	68	144	****
	3.65	2.19	5.30	
Fibromyalgia	444	211	224	*
	7.51	6.78	8.25	
Glaucoma	143	31	111	****
	2.42	1.00	4.09	

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 4B: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Age Group

	Total	Age Group		
	N %	**≤ 50 years** (N=3224)	**≥ 51 years** (N=2793)	**p-value**
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
Headaches/Migraines	1185 20.03	814 26.17	352 12.97	****
Hepatitis C	56 0.95	21 0.68	35 1.29	*
HIV/AIDS	43 0.73	13 0.42	30 1.10	**
Huntington's Disease	2 0.03	0 0.00	2 0.07	ns
Hypertension	318 5.38	112 3.60	200 7.37	****
Insomnia	2524 42.66	1434 46.11	1059 39.01	****
Loss of Appetite	744 12.58	529 17.01	203 7.48	****
Multiple Sclerosis	140 2.37	63 2.03	76 2.80	ns
Muscle Spasms	1050 17.75	542 17.43	494 18.20	ns
Muscular Dystrophy	15 0.25	9 0.29	6 0.22	ns
Nausea	955 16.14	638 20.51	298 10.98	****
Neuropathy	611 10.33	213 6.85	388 14.29	****
OCD	276 4.67	220 7.07	56 2.06	****
Opioid Use	133 2.25	76 2.44	55 2.03	ns
Osteoarthritis	466 7.88	95 3.05	359 13.22	****
PTSD	1005 16.99	634 20.39	352 12.97	****
Schizophrenia	17 0.29	14 0.45	3 0.11	*

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 4B: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Age Group

	Total	Age Group		
	N %	**≤ 50 years** (N=3224)	**≥ 51 years** (N=2793)	**p-value**
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
Seizures	114 1.93	71 2.28	40 1.47	*
Skin Conditions	149 2.52	84 2.70	65 2.39	ns
Sleep Apnea	536 9.06	263 8.46	266 9.80	ns
Stress	2408 40.70	1529 49.16	845 31.12	****
Tourette's Syndrome	18 0.30	13 0.42	5 0.18	ns
Tremors	126 2.13	60 1.93	66 2.43	ns
Vomiting	224 3.79	164 5.27	55 2.03	****
Wasting	31 0.52	17 0.55	14 0.52	ns
Weight Loss	243 4.11	149 4.79	91 3.35	**
Other	779 13.17	374 12.03	401 14.77	**

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 4C: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Education

	Total	Education		
	N %	< Bachelor's (N=2871)	≥ Bachelor's (N=3223)	p-value
Marijuana used for medical purposes	6111			ns
No	195	86	109	
	3.19	3.00	3.38	
Yes	5916	2785	3114	
	96.81	97.00	96.62	
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
ADHD	711	403	307	****
	12.02	14.47	9.86	
Alcohol Dependency	164	85	79	ns
	2.77	3.05	2.54	
Anxiety	3559	1784	1768	****
	60.16	64.06	56.78	
Arthritis	1563	835	725	****
	26.42	29.98	23.28	
Asthma	190	111	79	**
	3.21	3.99	2.54	
Bipolar Disorder	336	237	97	****
	5.68	8.51	3.11	
Bowel Distress	562	268	292	ns
	9.50	9.62	9.38	
Cancer	331	139	191	ns
	5.59	4.99	6.13	
Carpal Tunnel	214	138	76	****
	3.62	4.96	2.44	
Chronic Pain	2749	1460	1284	****
	46.47	52.42	41.23	
Crohn's Disease	159	64	95	ns
	2.69	2.30	3.05	
Depression	2463	1327	1128	****
	41.63	47.65	36.22	
Diabetes	216	131	84	****
	3.65	4.70	2.70	
Fibromyalgia	444	278	163	****
	7.51	9.98	5.23	
Glaucoma	143	68	75	ns
	2.42	2.44	2.41	

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 4C: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Education

	Total	Education		
	N %	**< Bachelor's** (N=2871)	**≥ Bachelor's** (N=3223)	**p-value**
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
Headaches/Migraines	1185	669	510	****
	20.03	24.02	16.38	
Hepatitis C	56	37	18	**
	0.95	1.33	0.58	
HIV/AIDS	43	27	16	*
	0.73	0.97	0.51	
Huntington's Disease	2	1	1	ns
	0.03	0.04	0.03	
Hypertension	318	180	137	***
	5.38	6.46	4.40	
Insomnia	2524	1213	1304	ns
	42.66	43.55	41.88	
Loss of Appetite	744	438	302	****
	12.58	15.73	9.70	
Multiple Sclerosis	140	68	72	ns
	2.37	2.44	2.31	
Muscle Spasms	1050	617	428	****
	17.75	22.15	13.74	
Muscular Dystrophy	15	10	5	ns
	0.25	0.36	0.16	
Nausea	955	514	436	****
	16.14	18.46	14.00	
Neuropathy	611	325	282	**
	10.33	11.67	9.06	
OCD	276	165	111	****
	4.67	5.92	3.56	
Opioid Use	133	98	35	****
	2.25	3.52	1.12	
Osteoarthritis	466	221	244	ns
	7.88	7.94	7.84	
PTSD	1005	626	377	****
	16.99	22.48	12.11	
Schizophrenia	17	14	3	**
	0.29	0.50	0.10	

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 4C: DPH Patient Survey Medical Use of Marijuana and Marijuana Product Use, Medical Conditions Treated by Education

	Total	Education		
	N %	**< Bachelor's** (N=2871)	**≥ Bachelor's** (N=3223)	**p-value**
Medical condition (s) for which respondent uses marijuana or marijuana products †‡	5916			
Seizures	114 1.93	74 2.66	38 1.22	****
Skin Conditions	149 2.52	73 2.62	76 2.44	ns
Sleep Apnea	536 9.06	315 11.31	221 7.10	****
Stress	2408 40.70	1266 45.46	1135 36.45	****
Tourette's Syndrome	18 0.30	10 0.36	8 0.26	ns
Tremors	126 2.13	71 2.55	54 1.73	*
Vomiting	224 3.79	127 4.56	95 3.05	**
Wasting	31 0.52	11 0.39	20 0.64	ns
Weight Loss	243 4.11	136 4.88	106 3.40	**
Other	779 13.17	347 12.46	430 13.81	ns

† *Among respondents indicating medical use of marijuana or marijuana products (certified or uncertified)*
‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Methods of Marijuana / Marijuana Product Administration

Tables 5A, 5B, and 5C summarize results of survey responses pertaining to methods of marijuana and marijuana product administration used in the past 30 days, with comparisons by gender, age group, and educational attainment, respectively. Respondents were asked additional questions regarding their typical use of marijuana and the methods of marijuana or marijuana product administration used in the past 30 days. Further, for each method of administration reported, respondents were asked to provide further detail on the frequency and amount of marijuana product used.
All respondents who indicated using marijuana at least once in the past 30 days where asked to indicated which methods of marijuana administration they used in the past 30 days. 16% of these respondents used only 1 method in the past 30 days, 26% used 2 methods, 26% used 3, and 31% used 4 or more. A larger proportion of respondents aged 51 or older than younger respondents reported using 1 or 2 methods (51% vs. 34%), while a larger proportion of younger respondents reported using 4 or 5+ methods (38% vs. 22%). A larger proportion of respondents without a Bachelor’s degree than with a degree reported using 4 or more methods (34% vs. 27%), while a larger proportion of older respondents than younger reported using 2 or 3 methods (56% vs. 49%).

All respondents who indicated using marijuana or marijuana products at least once in the past 30 days where asked to report on the amount of THC and CBD in their typical marijuana or marijuana product use. 45% of these respondents reported typical use of marijuana or marijuana products that contain higher amounts of THC, 34% reported approximately equal amounts of THC and CBD, and 14% reported higher amounts of CBD. Almost 7% of respondents reported that they did not know. A larger proportion of males than females reported using products higher in THC (53% vs. 37%), while a larger proportion of females than males reported using products with higher amounts of CBD (17% vs. 11%) or equal amounts of THC and CBD (37% vs. 31%). A larger proportion of respondents under the age of 51 compared to older respondents reported using products higher in THC (50% vs. 40%), while a larger proportion of older respondents compared to younger reported using products higher in CBD (17% vs. 11%) or not knowing (9% vs. 5%). A slightly higher proportion of respondents without a Bachelor’s degree than with a degree reported using products higher in THC or containing equal amounts of THC and CBD, while a slightly higher proportion of respondent with a Bachelor’s degree reported using products higher in CBD.

Respondents who indicated using marijuana or marijuana products at least once in the past 30 days were asked about different methods of marijuana or marijuana product administration used in the past 30 days. Over 2 in 3 respondents reported smoking dried flower (65%) or using vaporized concentrate (62%). 51% reported consuming edible marijuana products. Approximately 1 in 4 respondents reported using vaporized dried flower (28%), applied topical cannabis oil, ointment, lotion, cream, salve, etc. to the skin (27%), and sublingual or orally administered uptake products (23%). 16% of respondents reported using dabbed marijuana products, 11% using oral capsules or tablets, and 5% drinking marijuana infused products.

A significantly larger proportion of male respondents than female reported using vaporized dried flower and dabbed marijuana products. A significantly larger proportion of female respondents than male reported using sublingual or orally administered uptake products and topical cannabis oil, ointment, lotion, cream, salve, etc. to the skin. A significantly larger proportion of respondents under age 51 than older respondents reported smoking dried flower, using vaporized dried flower, vaporized concentrate, dabbed marijuana products, edible marijuana products, and drinkable marijuana products. A significantly larger proportion of respondents without a Bachelor’s degree than with a degree reported smoking dried flower and using dabbed marijuana products.

Table 5A: DPH Patient Survey Methods of Administration by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Gender		
		Male (N=3293)	**Female** (N=2720)	**p-value**
Number of administration methods used in the past 30 days				ns
0 methods	74 1.21	40 1.21	33 1.21	
1 method	953 15.59	555 16.85	387 14.23	
2 methods	1619 26.49	881 26.75	717 26.36	
3 methods	1598 26.15	833 25.30	744 27.35	
4 methods	1028 16.82	529 16.06	474 17.43	
5+ methods	839 13.73	455 13.82	365 13.42	
Typical marijuana / product use	6081			****
Higher in THC	2760 45.39	1722 52.50	999 36.96	
Higher in CBD	844 13.88	365 11.13	472 17.46	
Contain somewhat equal amounts of THC and CBD	2063 33.93	1010 30.79	1011 37.40	
Don't know / not sure	414 6.81	183 5.58	221 8.18	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continues) Table 5A: DPH Patient Survey Methods of Administration by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Gender		
	N %	**Male** (N=3293)	**Female** (N=2720)	**p-value**
Method of administration used (one time or more) in the past 30 days ‡				
Smoked dried flower	3921 65.12	2185 67.21	1667 62.39	***
Vaporized dried flower	1704 28.30	1033 31.77	642 24.03	****
Vaporized concentrated (cartridge/vape oil)	3751 62.30	2040 62.75	1647 61.64	ns
Dabbed marijuana products (butane hash oil, wax, shatter, etc.)	984 16.34	632 19.44	326 12.20	****
Ate marijuana products (brownies, cakes, cookies, etc.)	3074 51.05	1606 49.40	1410 52.77	**
Drank marijuana infused products (tea, cola, alcohol, etc.)	285 4.73	165 5.08	114 4.27	ns
Used sublingual (under the tongue) or orally administered uptake products (dissolvable strips, sublingual sprays, oil, tinctures, medicated lozenges, etc.)	1413 23.47	651 20.02	738 27.62	****
Used oral capsules/tablets	651 10.81	353 10.86	285 10.67	ns
Applied topical cannabis oil, ointment, lotion, cream, slave, etc. to skin	1600 26.57	638 19.62	933 34.92	****
Used rectal/vaginal cannabis suppositories	75 1.25	32 0.98	39 1.46	ns
Other	96 1.59	49 1.51	46 1.72	ns

‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 5B: DPH Patient Survey Methods of Administration by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Age Group ≤ 50 years (N=3224)	 ≥ 51 years (N=2793)	 p-value
Number of administration methods used in the past 30 days				****
0 methods	74 1.21	34 1.05	37 1.32	
1 method	953 15.59	381 11.82	554 19.84	
2 methods	1619 26.49	724 22.46	858 30.72	
3 methods	1598 26.15	861 26.71	721 25.81	
4 methods	1028 16.82	632 19.60	381 13.64	
5+ methods	839 13.73	592 18.36	242 8.66	
Typical marijuana / product use	6081			****
Higher in THC	2760 45.39	1594 49.67	1123 40.42	
Higher in CBD	844 13.88	365 11.37	463 16.67	
Contain somewhat equal amounts of THC and CBD	2063 33.93	1100 34.28	935 33.66	
Don't know / not sure	414 6.81	150 4.67	257 9.25	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 5B: DPH Patient Survey Methods of Administration by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Age Group		
	N **%**	**≤ 50 years** (N=3224)	**≥ 51 years** (N=2793)	**p-value**
Method of administration used (one time or more) in the past 30 days ‡				
Smoked dried flower	3921 65.12	2296 72.22	1573 57.24	****
Vaporized dried flower	1704 28.30	975 30.67	706 25.69	****
Vaporized concentrated (cartridge/vape oil)	3751 62.30	2174 68.39	1523 55.42	****
Dabbed marijuana products (butane hash oil, wax, shatter, etc.)	984 16.34	727 22.87	250 9.10	****
Ate marijuana products (brownies, cakes, cookies, etc.)	3074 51.05	1878 59.08	1166 42.43	****
Drank marijuana infused products (tea, cola, alcohol, etc.)	285 4.73	203 6.39	79 2.87	****
Used sublingual (under the tongue) or orally administered uptake products (dissolvable strips, sublingual sprays, oil, tinctures, medicated lozenges, etc.)	1413 23.47	692 21.77	708 25.76	***
Used oral capsules/tablets	651 10.81	357 11.23	285 10.37	ns
Applied topical cannabis oil, ointment, lotion, cream, slave, etc. to skin	1600 26.57	803 25.26	770 28.02	*
Used rectal/vaginal cannabis suppositories	75 1.25	48 1.51	26 0.95	ns
Other	96 1.59	45 1.42	49 1.78	ns

‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 5C: DPH Patient Survey Methods of Administration by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Education		
	N %	**< Bachelor's** (N=2871)	**≥ Bachelor's** (N=3223)	**p-value**
Number of administration methods used in the past 30 days				****
0 methods	74	44	30	
	1.21	1.53	0.93	
1 method	953	447	502	
	15.59	15.57	15.58	
2 methods	1619	721	892	
	26.49	25.11	27.68	
3 methods	1598	679	917	
	26.15	23.65	28.45	
4 methods	1028	521	503	
	16.82	18.15	15.61	
5+ methods	839	459	379	
	13.73	15.99	11.76	
Typical marijuana / product use	6081			**
Higher in THC	2760	1323	1433	
	45.39	46.36	44.64	
Higher in CBD	844	351	488	
	13.88	12.30	15.20	
Contain somewhat equal amounts of THC	2063	1005	1053	
and CBD	33.93	35.21	32.80	
Don't know / not sure	414	175	236	
	6.81	6.13	7.35	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

Table 5C: DPH Patient Survey Methods of Administration by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Education		
	N %	**< Bachelor's** (N=2871)	**≥ Bachelor's** (N=3223)	**p-value**
Method of administration used (one time or more) in the past 30 days ‡				
Smoked dried flower	3921 65.12	2052 72.36	1861 58.74	****
Vaporized dried flower	1704 28.30	742 26.16	956 30.18	***
Vaporized concentrated (cartridge/vape oil)	3751 62.30	1816 64.03	1925 60.76	**
Dabbed marijuana products (butane hash oil, wax, shatter, etc.)	984 16.34	595 20.98	389 12.28	****
Ate marijuana products (brownies, cakes, cookies, etc.)	3074 51.05	1452 51.20	1615 50.98	ns
Drank marijuana infused products (tea, cola, alcohol, etc.)	285 4.73	160 5.64	125 3.95	**
Used sublingual (under the tongue) or orally administered uptake products (dissolvable strips, sublingual sprays, oil, tinctures, medicated lozenges, etc.)	1413 23.47	613 21.61	796 25.13	**
Used oral capsules/tablets	651 10.81	277 9.77	373 11.77	*
Applied topical cannabis oil, ointment, lotion, cream, slave, etc. to skin	1600 26.57	761 26.83	835 26.36	ns
Used rectal/vaginal cannabis suppositories	75 1.25	34 1.20	41 1.29	ns
Other	96 1.59	50 1.76	46 1.45	ns

‡ *Percentages sum to more than 100% because respondents could choose more than one option*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Smoking Dried Flower

Tables 6A, 6B, and 6C summarize results of survey responses pertaining to smoking dried flower, with comparisons by gender, age group, and educational attainment, respectively. 65% of respondents who reported using marijuana or marijuana products in the past 30 days reported using smoked dried flower in a joint, bong, pipe, blunt, etc. the past 30 days. Smoking dried flower was significantly higher among respondents under age 51 compared to older respondents (72% vs. 57%) and respondents without a Bachelor's degree compared to respondents with at least a Bachelor's degree (72% vs. 59%).

Thirty-one percent of respondents who reported smoking dried flower in the past 30 days reported smoking dried flower multiple times per day, while 21% reported smoking dried flower less than once per week. A significantly larger proportion of respondents without a Bachelor's degree than with a degree reported smoking dried flower multiple times per day (37% vs. 24%), while a larger proportion of respondents with a Bachelor's degree than without reported smoking dried flower less than once per week (25% vs. 17%) and more than once per week (but not as much as once per day) (34% vs. 27%).

Thirty-seven percent of respondents who reported smoking dried flower in the past 30 days reported using less than 1/8 oz. of dried flower in the past 30 days, 30% reported using between 1/8 and 1/2 oz., 22% reported using between 1/2 and 1 oz., and 6% reported using more than one oz. A larger proportion of male respondents than female reported using more than 1 oz. (8% vs. 4%), while a larger proportion of female respondents than male reported using no more than 1/8 oz. (42% vs. 33%) or an unknown amount (8% vs. 4%). A larger proportion of respondents less than 51 years old than older respondents reported using between 1/2 and 1 oz. (23% vs. 20%) and more than one oz. (7% vs. 5%), while a larger proportion of respondents older than 50 reported using up to 1/8 oz. (41% vs 34%) or between 1/8 and 1/4 oz. (15% vs. 13%). A larger proportion of respondents without a Bachelor's degree than with a degree reported using between 1/4 and 1/2 oz. (17% vs. 14%), 1/2 and 1 oz. (26% vs. 17%), and more than one oz. (8% vs. 4%). A larger proportion of respondents with a Bachelor's degree reported using up to 1/8 oz. (46% vs. 29%) and between 1/8 and 1/4 oz. (16% vs. 13%).

Table 6A: DPH Patient Survey Smoked Dried Flower by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Gender		
	N **%**	**Male** (N=3251)	**Female** (N=2672)	**p-value**
Smoked dried flower in the past 30 days	6021			***
No	2100	1066	1005	
	34.88	32.79	37.61	
Yes	3921	2185	1667	
	65.12	67.21	62.39	
Frequency of smoking dried flower in a joint, bong, pipe, blunt, etc. †	3804			**
Less than once per week	802	404	386	
	21.08	19.13	23.75	
More than once per week (but not as much	1142	645	475	
as once per day)	30.02	30.54	29.23	
Once per day	693	390	295	
	18.22	18.47	18.15	
Multiple times per day	1167	673	469	
	30.68	31.87	28.86	
Total amount of dried flower smoked over past 30 days †	3827			****
0 to 1/8 ounce	1411	702	686	
	36.87	32.93	42.11	
1/8 to 1/4 ounce	537	316	212	
	14.03	14.82	13.01	
1/4 to 1/2 ounce	596	343	242	
	15.57	16.09	14.86	
1/2 to 1 ounce	835	521	303	
	21.82	24.44	18.60	
More than 1 ounce	228	162	62	
	5.96	7.60	3.81	
Don't know/not sure	220	88	124	
	5.75	4.13	7.61	

† *Among respondents reporting smoking dried flower in past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 6B: DPH Patient Survey Smoked Dried Flower by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Age Group		
	N %	≤ 50 years (N=3179)	≥ 51 years (N=2748)	p-value
Smoked dried flower in the past 30 days	6021			****
No	2100	883	1175	
	34.88	27.78	42.76	
Yes	3921	2296	1573	
	65.12	72.22	57.24	
Frequency of smoking dried flower in a joint, bong, pipe, blunt, etc. †	3804			*
Less than once per week	802	490	303	
	21.08	22.00	19.86	
More than once per week (but not as much as once per day)	1142	648	479	
	30.02	29.10	31.39	
Once per day	693	382	301	
	18.22	17.15	19.72	
Multiple times per day	1167	707	443	
	30.68	31.75	29.03	
Total amount of dried flower smoked over past 30 days †	3827			****
0 to 1/8 ounce	1411	766	631	
	36.87	34.15	41.11	
1/8 to 1/4 ounce	537	295	235	
	14.03	13.15	15.31	
1/4 to 1/2 ounce	596	362	223	
	15.57	16.14	14.53	
1/2 to 1 ounce	835	521	300	
	21.82	23.23	19.54	
More than 1 ounce	228	158	69	
	5.96	7.04	4.50	
Don't know/not sure	220	141	77	
	5.75	6.29	5.02	

† *Among respondents reporting smoking dried flower in past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 6C: DPH Patient Survey Smoked Dried Flower by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Education		
	N **%**	**< Bachelor's** (N=2836)	**≥ Bachelor's** (N=3168)	**p-value**
Smoked dried flower in the past 30 days	6021			****
No	2100	784	1307	
	34.88	27.64	41.26	
Yes	3921	2052	1861	
	65.12	72.36	58.74	
Frequency of smoking dried flower in a joint, bong, pipe, blunt, etc. †	3804			****
Less than once per week	802	339	461	
	21.08	17.14	25.36	
More than once per week (but not as much	1142	526	613	
as once per day)	30.02	26.59	33.72	
Once per day	693	383	310	
	18.22	19.36	17.05	
Multiple times per day	1167	730	434	
	30.68	36.91	23.87	
Total amount of dried flower smoked over past 30 days †	3827			****
0 to 1/8 ounce	1411	572	835	
	36.87	28.66	45.80	
1/8 to 1/4 ounce	537	250	285	
	14.03	12.53	15.63	
1/4 to 1/2 ounce	596	347	249	
	15.57	17.38	13.66	
1/2 to 1 ounce	835	528	307	
	21.82	26.45	16.84	
More than 1 ounce	228	163	65	
	5.96	8.17	3.57	
Don't know/not sure	220	136	82	
	5.75	6.81	4.50	

† *Among respondents reporting smoking dried flower in past 30 days*
$p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$; $^{****}p<0.0001$; ns=not significant

Vaporized Marijuana Concentrate

Tables 8A, 8B, and 8C summarize results of survey responses pertaining to using vaporized marijuana concentrated, with comparisons by gender, age group, and educational attainment, respectively. 62% of respondents who reported using marijuana or marijuana products at least once in the past 30 days reported using vaporized marijuana concentrate in the past 30 days. Vaporized marijuana concentrate use was significantly higher among respondents under age 51 compared to older respondents (68% vs. 55%).

Thirty-six percent of respondents who reported using vaporized marijuana concentrate in the past 30 days reported using vaporized marijuana concentrate at least once per day, while 26% reported using vaporized marijuana concentrate less than once per week. A larger proportion of respondents without a Bachelor’s degree than with a degree reported using vaporized marijuana concentrate multiple times per day (25% vs. 19%) and once per day (16% vs. 13%), while a larger proportion of respondents with a Bachelor's degree than without reported using vaporized marijuana concentrate less than once per week (27% vs. 24%) and more than once per week (but not as much as once per day) (41% vs. 34%).

All respondents who reported using vaporized marijuana concentrate in the past 30 days were asked to indicate the amount of THC administered using vaporized marijuana concentrate over the past 30 days. The amount of THC reported by respondents should be interpreted with caution, as almost half of all respondents did not know how much THC they administered using vaporized marijuana concentrate. However, 40% of respondents reported administering between 1 and 150 mg of THC in the past 30 days using vaporized marijuana concentrate. A larger proportion of male respondents than female reported administering between 1 and 150 mg of THC (41% vs. 38%), while a larger proportion of female respondents than male reported that they did not know how much THC they administered using vaporized marijuana concentrate (51% vs. 42%). A larger proportion of respondents over the age of 50 than younger respondents reported that they did not know how much THC they administered using vaporized marijuana concentrate (50% vs. 43%).

All respondents who reported using vaporize marijuana concentrate in the past 30 days were asked to indicate the amount of CBD administered using vaporized marijuana concentrate over the past 30 days. The amount of CBD reported by respondents should be interpreted with caution, as more than 2 in 5 respondents did not know how much CBD they administered using vaporized marijuana concentrate. However, 38% of respondents reported administering between 1 and 150 mg of CBD in the past 30 days using vaporized marijuana concentrate. A larger proportion of male respondents than female reported administering between 1 and 150 mg of CBD (39% vs. 36%), while a larger proportion of female respondents than male reported that they did not know how much CBD they administered using vaporized marijuana concentrate (49% vs. 40%). A larger proportion of respondents over the age of 50 than younger respondents reported that they did not know how much CBD they administered using vaporized marijuana concentrate (48% vs. 41%), as did a larger proportion of respondents with a Bachelor's degree than without a degree (45% vs. 42%).

Table 8A: DPH Patient Survey Vaporized Marijuana Concentrate by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Gender Male (N=3251)	Female (N=2672)	p-value
Used vaporized marijuana concentrate in past 30 days	6021			ns
No	2270	1211	1025	
	37.70	37.25	38.36	
Yes	3751	2040	1647	
	62.30	62.75	61.64	
Frequency of using vaporized marijuana concentrate †	3551			ns
Less than once per week	909	500	397	
	25.60	25.75	25.61	
More than once per week (but not as much as once per day)	1346	770	556	
	37.90	39.65	35.87	
Once per day	505	261	234	
	14.22	13.44	15.10	
Multiple times per day	791	411	363	
	22.28	21.16	23.42	
Amount of THC administered † ‡	3661			****
0 mg past 30 days	58	21	37	
	1.58	1.06	2.30	
Between 1 and 150 mg in past 30 days	1447	818	607	
	39.52	41.15	37.66	
Between 151 and 300 mg in past 30 days	288	194	90	
	7.87	9.76	5.58	
More than 300 mg in past 30 days	182	123	53	
	4.97	6.19	3.29	
Don't know/not sure	1686	832	825	
	46.05	41.85	51.18	
Amount of CBD administered † ‡	3635			****
0 mg past 30 days	428	265	159	
	11.77	13.47	9.89	
Between 1 and 150 mg in past 30 days	1368	764	581	
	37.63	38.82	36.15	
Between 151 and 300 mg in past 30 days	198	116	76	
	5.45	5.89	4.73	
More than 300 mg in past 30 days	39	28	11	
	1.07	1.42	0.68	
Don't know/not sure	1602	795	780	
	44.07	40.40	48.54	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 8B: 2018 Marijuana Survey Results - Vaporized Marijuana Concentrate by Age Group *(Among 6111 respondents indicating marijuana use in past 30 days)*

	Total	Age Group		
	N %	**≤ 50 years** (N=3179)	**≥ 51 years** (N=2748)	**p-value**
Used vaporized marijuana concentrate in past 30 days	6021			****
No	2270	1005	1225	
	37.70	31.61	44.58	
Yes	3751	2174	1523	
	62.30	68.39	55.42	
Frequency of using vaporized marijuana concentrate †	3551			*
Less than once per week	909	543	351	
	25.60	26.36	24.32	
More than once per week (but not as much as once per day)	1346	770	559	
	37.90	37.38	38.74	
Once per day	505	269	230	
	14.22	13.06	15.94	
Multiple times per day	791	478	303	
	22.28	23.20	21.00	
Amount of THC administered † ‡	3661			****
0 mg past 30 days	58	27	30	
	1.58	1.27	2.02	
Between 1 and 150 mg in past 30 days	1447	839	588	
	39.52	39.56	39.54	
Between 151 and 300 mg in past 30 days	288	198	88	
	7.87	9.34	5.92	
More than 300 mg in past 30 days	182	143	36	
	4.97	6.74	2.42	
Don't know/not sure	1686	914	745	
	46.05	43.09	50.10	
Amount of CBD administered † ‡	3635			****
0 mg past 30 days	428	258	160	
	11.77	12.22	10.88	
Between 1 and 150 mg in past 30 days	1368	814	536	
	37.63	38.56	36.44	
Between 151 and 300 mg in past 30 days	198	137	59	
	5.45	6.49	4.01	
More than 300 mg in past 30 days	39	32	7	
	1.07	1.52	0.48	
Don't know/not sure	1602	870	709	
	44.07	41.21	48.20	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 8C: 2018 Marijuana Survey Results - Vaporized Marijuana Concentrate by Education *(Among 6111 respondents indicating marijuana use in past 30 days)*

	Total	Education		
	N %	**< Bachelor's** (N=2836)	**≥ Bachelor's** (N=3168)	**p-value**
Used vaporized marijuana concentrate in past 30 days	6021			**
No	2270	1020	1243	
	37.70	35.97	39.24	
Yes	3751	1816	1925	
	62.30	64.03	60.76	
Frequency of using vaporized marijuana concentrate †	3551			****
Less than once per week	909	412	495	
	25.60	24.36	26.73	
More than once per week (but not as much as once per day)	1346	582	763	
	37.90	34.42	41.20	
Once per day	505	266	238	
	14.22	15.73	12.85	
Multiple times per day	791	431	356	
	22.28	25.49	19.22	
Amount of THC administered † ‡	3661			***
0 mg past 30 days	58	21	37	
	1.58	1.19	1.96	
Between 1 and 150 mg in past 30 days	1447	689	756	
	39.52	39.04	40.06	
Between 151 and 300 mg in past 30 days	288	152	136	
	7.87	8.61	7.21	
More than 300 mg in past 30 days	182	109	73	
	4.97	6.18	3.87	
Don't know/not sure	1686	794	885	
	46.05	44.99	46.90	
Amount of CBD administered † ‡	3635			****
0 mg past 30 days	428	204	224	
	11.77	11.63	11.97	
Between 1 and 150 mg in past 30 days	1368	655	711	
	37.63	37.34	37.98	
Between 151 and 300 mg in past 30 days	198	123	75	
	5.45	7.01	4.01	
More than 300 mg in past 30 days	39	28	11	
	1.07	1.60	0.59	
Don't know/not sure	1602	744	851	
	44.07	42.42	45.46	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Dabbed Marijuana Products

Tables 9A, 9B, and 9C summarize results of survey responses pertaining to dabbing marijuana products, with comparisons by gender, age group, and educational attainment, respectively. 16% of respondents who indicated using marijuana or marijuana products at least once in the past 30 days reported using dabbed marijuana products in the past 30 days. Dabbing was significantly higher among male respondents compared to female (19% vs. 12%), respondents under age 51 compared to older respondents (23% vs. 9%), and respondents without a Bachelor's degree compared to respondents with a degree (21% vs. 12%).

Twenty-eighty percent of respondents who reported dabbing marijuana products in the past 30 days reported dabbing marijuana products at least once per day, while 45% reported dabbing less than once per week. There were no significant differences in reported dabbing by gender, age, or education.

All respondents who reported dabbing marijuana products in the past 30 days were asked to indicate the amount of THC administered by dabbing marijuana products over the past 30 days. The amount of THC reported by respondents should be interpreted with caution, as more than 2 in 5 respondents did not know how much THC they administered through dabbing marijuana products. However, 39% of respondents reported administering between 1 and 150 mg of THC in the past 30 days by dabbing marijuana products. A larger proportion of respondents over the age of 50 than younger respondents reported that they did not know how much THC they administered using vaporized marijuana concentrate (47% vs. 41%).

All respondents who reported dabbing marijuana products in the past 30 days were asked to indicate the amount of CBD administered by dabbing marijuana products over the past 30 days. The amount of CBD reported by respondents should be interpreted with caution, as approximately 2 in 5 respondents did not know how much CBD they administered through dabbing marijuana products. However, 35% of respondents reported administering between 1 and 150 mg of CBD in the past 30 days by dabbing.

Table 9A: DPH Patient Survey Dabbing Marijuana Products by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Gender		
		Male (N=3251)	**Female** (N=2672)	**p-value**
Dabbed marijuana products in the past 30 days	6021			****
No	5037	2619	2346	
	83.66	80.56	87.80	
Yes	984	632	326	
	16.34	19.44	12.20	
Frequency of dabbing marijuana †	911			ns
Less than once per week	408	259	139	
	44.79	44.43	45.57	
More than once per week (but not as much as once per day)	247	156	86	
	27.11	26.76	28.20	
Once per day	84	58	23	
	9.22	9.95	7.54	
Multiple times per day	172	110	57	
	18.88	18.87	18.69	
Amount of THC administered † ‡	952			**
0 mg past 30 days	17	11	6	
	1.79	1.80	1.89	
Between 1 and 150 mg in past 30 days	374	230	133	
	39.29	37.70	41.82	
Between 151 and 300 mg in past 30 days	105	80	22	
	11.03	13.11	6.92	
More than 300 mg in past 30 days	51	40	10	
	5.36	6.56	3.14	
Don't know/not sure	405	249	147	
	42.54	40.82	46.23	
Amount of CBD administered † ‡	951			ns
0 mg past 30 days	165	107	54	
	17.35	17.60	16.93	
Between 1 and 150 mg in past 30 days	334	214	113	
	35.12	35.20	35.42	
Between 151 and 300 mg in past 30 days	56	40	15	
	5.89	6.58	4.70	
More than 300 mg in past 30 days	7	3	4	
	0.74	0.49	1.25	
Don't know/not sure	389	244	133	
	40.90	40.13	41.69	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 9B: DPH Patient Survey Dabbing Marijuana Products by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Age Group		
	N %	**≤ 50 years** (N=3179)	**≥ 51 years** (N=2748)	**p-value**
Dabbed marijuana products in the past 30 days	6021			****
No	5037	2452	2498	
	83.66	77.13	90.90	
Yes	984	727	250	
	16.34	22.87	9.10	
Frequency of dabbing marijuana †	911			ns
Less than once per week	408	299	107	
	44.79	43.78	48.20	
More than once per week (but not as much as once per day)	247	181	63	
	27.11	26.50	28.38	
Once per day	84	67	17	
	9.22	9.81	7.66	
Multiple times per day	172	136	35	
	18.88	19.91	15.77	
Amount of THC administered † ‡	952			****
0 mg past 30 days	17	7	10	
	1.79	0.99	4.15	
Between 1 and 150 mg in past 30 days	374	273	101	
	39.29	38.78	41.91	
Between 151 and 300 mg in past 30 days	105	93	10	
	11.03	13.21	4.15	
More than 300 mg in past 30 days	51	44	6	
	5.36	6.25	2.49	
Don't know/not sure	405	287	114	
	42.54	40.77	47.30	
Amount of CBD administered † ‡	951			*
0 mg past 30 days	165	122	41	
	17.35	17.38	16.94	
Between 1 and 150 mg in past 30 days	334	244	87	
	35.12	34.76	35.95	
Between 151 and 300 mg in past 30 days	56	51	5	
	5.89	7.26	2.07	
More than 300 mg in past 30 days	7	7	0	
	0.74	1.00	0.00	
Don't know/not sure	389	278	109	
	40.90	39.60	45.04	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 9C: DPH Patient Survey Dabbing Marijuana Products by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

Table 9C: 2018 Marijuana Survey Results - DABBING MARIJUANA PRODUCTS by EDUCATION *(Among 6111 respondents indicating marijuana use in past 30 days)*				
	Total	**Education**		
	N %	**< Bachelor's** (N=2836)	**≥ Bachelor's** (N=3168)	**p-value**
Dabbed marijuana products in the past 30 days	6021			****
No	5037 83.66	2241 79.02	2779 87.72	
Yes	984 16.34	595 20.98	389 12.28	
Frequency of dabbing marijuana †	911			ns
Less than once per week	408 44.79	237 43.25	171 47.11	
More than once per week (but not as much as once per day)	247 27.11	145 26.46	102 28.10	
Once per day	84 9.22	51 9.31	33 9.09	
Multiple times per day	172 18.88	115 20.99	57 15.70	
Amount of THC administered † ‡	952			ns
0 mg past 30 days	17 1.79	10 1.74	7 1.85	
Between 1 and 150 mg in past 30 days	374 39.29	229 39.90	145 38.36	
Between 151 and 300 mg in past 30 days	105 11.03	68 11.85	37 9.79	
More than 300 mg in past 30 days	51 5.36	32 5.57	19 5.03	
Don't know/not sure	405 42.54	235 40.94	170 44.97	
Amount of CBD administered † ‡	951			ns
0 mg past 30 days	165 17.35	91 15.88	74 19.58	
Between 1 and 150 mg in past 30 days	334 35.12	210 36.65	124 32.80	
Between 151 and 300 mg in past 30 days	56 5.89	41 7.16	15 3.97	
More than 300 mg in past 30 days	7 0.74	5 0.87	2 0.53	
Don't know/not sure	389 40.90	226 39.44	163 43.12	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Edible Marijuana Products

Tables 10A, 10B, and 10C summarize results of survey responses pertaining to consuming edible marijuana products, with comparisons by gender, age group, and educational attainment, respectively. 51% of respondents who reported using marijuana at least once in the past 30 days reported using edible marijuana products in the past 30 days. A larger proportion of female respondents than male (53% vs. 49%) and respondents under age 50 than older (59% vs. 42%) reported edible marijuana use.

Twelve percent of respondents who reported using edible marijuana products in the past 30 days reported using these products at least once per day, while 61% reported using these products less than once per week. A larger proportion of respondents less than 51 years old than older respondents reported using edible marijuana products less than once per week (66% vs. 52%), while a larger proportion of older respondents than younger reported these products more than once per week (31% vs. 25%) and once per day (14% vs. 7%).

All respondents who used edible marijuana products in the past 30 days were asked to indicate the amount of THC administered by using these products over the past 30 days. The amount of THC reported by respondents should be interpreted with caution, as almost 1 in 4 respondents did not know how much THC they administered. However, 59% of respondents reported administering between 1 and 150 mg of THC in the past 30 days by through edible marijuana products. A larger proportion of male respondents than female reported administering between 150 and 300 mg of THC (13% vs. 8%), while a larger proportion of female respondents than male reported that they did not know (27% vs. 22%). A larger proportion of respondents under the age of 51 than older respondents reported administering between 150 and 300 mg of THC (12% vs. 9%), while a larger proportion of older respondents than younger reported that they did not know how much THC they administered through edible marijuana products (27% vs. 23%). A larger proportion of respondents with a Bachelor's degree than respondents without a degree reported administering between 1 and 150 mg of THC through edible marijuana products (63% vs. 54%), while a larger proportion of respondents without a Bachelor's degree reported that they did not know (28% vs. 22%).

All respondents who used edible marijuana products in the past 30 days were asked to indicate the amount of CBD administered by using edible marijuana products over the past 30 days. The amount of CBD reported by respondents should be interpreted with caution, as approximately 1 in 3 respondents did not know how much CBD they administered through edible marijuana products. However, 45% of respondents reported administering between 1 and 150 mg of CBD in the past 30 days through edible marijuana products.

Table 10A: DPH Patient Survey Edible Marijuana Products by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Gender		
	N %	**Male** (N=3251)	**Female** (N=2672)	**p-value**
Used edible marijuana or marijuana products in the past 30 days	6021			**
No	2947	1645	1262	
	48.95	50.60	47.23	
Yes	3074	1606	1410	
	51.05	49.40	52.77	
Frequency of using edible marijuana or marijuana products †	2941			*
Less than once per week	1781	937	806	
	60.56	61.24	59.48	
More than once per week (but not as much as once per day)	798	431	357	
	27.13	28.17	26.35	
Once per day	284	128	151	
	9.66	8.37	11.14	
Multiple times per day	78	34	41	
	2.65	2.22	3.03	
Amount of THC administered † ‡	3000			****
0 mg past 30 days	80	36	44	
	2.67	2.30	3.19	
Between 1 and 150 mg in past 30 days	1770	918	817	
	59.00	58.70	59.20	
Between 151 and 300 mg in past 30 days	332	211	112	
	11.07	13.49	8.12	
More than 300 mg in past 30 days	82	52	28	
	2.73	3.32	2.03	
Don't know/not sure	736	347	379	
	24.53	22.19	27.46	
Amount of CBD administered † ‡	2981			***
0 mg past 30 days	488	284	194	
	16.37	18.36	14.08	
Between 1 and 150 mg in past 30 days	1332	688	619	
	44.68	44.47	44.92	
Between 151 and 300 mg in past 30 days	134	77	53	
	4.50	4.98	3.85	
More than 300 mg in past 30 days	28	20	8	
	0.94	1.29	0.58	
Don't know/not sure	999	478	504	
	33.51	30.90	36.57	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 10B: DPH Patient Survey Edible Marijuana Products by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Age Group		
	N %	**≤ 50 years** (N=3179)	**≥ 51 years** (N=2748)	**p-value**
Used edible marijuana or marijuana products in the past 30 days	6021			****
No	2947	1301	1582	
	48.95	40.92	57.57	
Yes	3074	1878	1166	
	51.05	59.08	42.43	
Frequency of using edible marijuana or marijuana products †	2941			****
Less than once per week	1781	1181	584	
	60.56	65.76	52.19	
More than once per week (but not as much as once per day)	798	450	343	
	27.13	25.06	30.65	
Once per day	284	121	159	
	9.66	6.74	14.21	
Multiple times per day	78	44	33	
	2.65	2.45	2.95	
Amount of THC administered † ‡	3000			****
0 mg past 30 days	80	39	39	
	2.67	2.13	3.41	
Between 1 and 150 mg in past 30 days	1770	1083	672	
	59.00	59.28	58.74	
Between 151 and 300 mg in past 30 days	332	222	106	
	11.07	12.15	9.27	
More than 300 mg in past 30 days	82	65	17	
	2.73	3.56	1.49	
Don't know/not sure	736	418	310	
	24.53	22.88	27.10	
Amount of CBD administered † ‡	2981			***
0 mg past 30 days	488	325	156	
	16.37	17.86	13.78	
Between 1 and 150 mg in past 30 days	1332	805	514	
	44.68	44.23	45.41	
Between 151 and 300 mg in past 30 days	134	94	39	
	4.50	5.16	3.45	
More than 300 mg in past 30 days	28	21	7	
	0.94	1.15	0.62	
Don't know/not sure	999	575	416	
	33.51	31.59	36.75	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 10C: DPH Patient Survey Edible Marijuana Products by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

Table 10C: 2018 Marijuana Survey Results - EDIBLE MARIJUANA PRODUCTS by EDUCATION
(Among 6111 respondents indicating marijuana use in past 30 days)

	Total	**Education**		
	N **%**	**< Bachelor's** (N=2836)	**≥ Bachelor's** (N=3168)	**p-value**
Used edible marijuana or marijuana products in the past 30 days	6021			ns
No	2947	1384	1553	
	48.95	48.80	49.02	
Yes	3074	1452	1615	
	51.05	51.20	50.98	
Frequency of using edible marijuana or marijuana products †	2941			**
Less than once per week	1781	845	930	
	60.56	61.19	59.88	
More than once per week (but not as much as once per day)	798	357	441	
	27.13	25.85	28.40	
Once per day	284	129	155	
	9.66	9.34	9.98	
Multiple times per day	78	50	27	
	2.65	3.62	1.74	
Amount of THC administered † ‡	3000			****
0 mg past 30 days	80	43	37	
	2.67	3.04	2.35	
Between 1 and 150 mg in past 30 days	1770	767	1001	
	59.00	54.17	63.47	
Between 151 and 300 mg in past 30 days	332	171	161	
	11.07	12.08	10.21	
More than 300 mg in past 30 days	82	45	37	
	2.73	3.18	2.35	
Don't know/not sure	736	390	341	
	24.53	27.54	21.62	
Amount of CBD administered † ‡	2981			*
0 mg past 30 days	488	210	277	
	16.37	14.91	17.69	
Between 1 and 150 mg in past 30 days	1332	629	701	
	44.68	44.67	44.76	
Between 151 and 300 mg in past 30 days	134	74	60	
	4.50	5.26	3.83	
More than 300 mg in past 30 days	28	18	10	
	0.94	1.28	0.64	
Don't know/not sure	999	477	518	
	33.51	33.88	33.08	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Drinkable Marijuana Products

Tables 11A, 11B, and 11C summarize results of survey responses pertaining to consuming drinkable marijuana products, with comparisons by gender, age group, and educational attainment, respectively. 5% of respondents who reported using marijuana or marijuana products at least once in the past 30 days reported using drinkable marijuana products in the past 30 days. Consuming drinkable marijuana products was significantly higher among respondents under age 51 compared to older respondents (6% vs. 3%) and respondents without a Bachelor's degree compared to respondents with a degree (6% vs. 4%).

Nine percent of respondents who reported drinking marijuana products in the past 30 days reported drinking marijuana products at least once per day, while 81% reported drinking marijuana products less than once per week.
All respondents who reported drinking marijuana products in the past 30 days were asked to indicate the amount of THC administered by drinking marijuana products over the past 30 days. The amount of THC reported by respondents should be interpreted with caution, as almost 1 in 5 respondents did not know how much THC they administered through drinking marijuana products. However, 60% of respondents reported administering between 1 and 150 mg of THC in the past 30 days by drinking marijuana products.

All respondents who reported drinking marijuana products in the past 30 days were asked to indicate the amount of CBD administered by drinking marijuana products over the past 30 days. The amount of CBD reported by respondents should be interpreted with caution, as approximately 1 in 4 respondents did not know how much CBD they administered through drinking marijuana products. However, 43% of respondents reported administering between 1 and 150 mg of CBD in the past 30 days through edible marijuana products. There were no significant differences in the amount of CBD administered by drinking marijuana products by gender, age, or education.

Table 11A: DPH Patient Drinking Marijuana Products by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Gender		
		Male (N=3251)	**Female** (N=2672)	**p-value**
Drank marijuana infused products in the past 30 days	6021			ns
No	5736	3086	2558	
	95.27	94.92	95.73	
Yes	285	165	114	
	4.73	5.08	4.27	
Frequency of drinking marijuana infused products †	258			ns
Less than once per week	209	117	86	
	81.01	80.14	81.13	
More than once per week (but not as much as once per day)	26	16	10	
	10.08	10.96	9.43	
Once per day	15	6	9	
	5.81	4.11	8.49	
Multiple times per day	8	7	1	
	3.10	4.79	0.94	
Amount of THC administered † ‡	277			ns
0 mg past 30 days	25	14	11	
	9.03	8.75	9.91	
Between 1 and 150 mg in past 30 days	166	93	67	
	59.93	58.13	60.36	
Between 151 and 300 mg in past 30 days	26	14	12	
	9.39	8.75	10.81	
More than 300 mg in past 30 days	4	3	1	
	1.44	1.88	0.90	
Don't know/not sure	56	36	20	
	20.22	22.50	18.02	
Amount of CBD administered † ‡	275			ns
0 mg past 30 days	71	45	25	
	25.82	28.13	22.94	
Between 1 and 150 mg in past 30 days	119	62	53	
	43.27	38.75	48.62	
Between 151 and 300 mg in past 30 days	12	6	6	
	4.36	3.75	5.50	
More than 300 mg in past 30 days	2	2	0	
	0.73	1.25	0.00	
Don't know/not sure	71	45	25	
	25.82	28.13	22.94	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 11B: DPH Patient Drinking Marijuana Products by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Age Group		
	N %	**≤ 50 years** (N=3179)	**≥ 51 years** (N=2748)	**p-value**
Drank marijuana infused products in the past 30 days	6021			****
No	5736 95.27	2976 93.61	2669 97.13	
Yes	285 4.73	203 6.39	79 2.87	
Frequency of drinking marijuana infused products †	258			**
Less than once per week	209 81.01	158 85.87	49 69.01	
More than once per week (but not as much as once per day)	26 10.08	17 9.24	9 12.68	
Once per day	15 5.81	5 2.72	10 14.08	
Multiple times per day	8 3.10	4 2.17	3 4.23	
Amount of THC administered † ‡	277			ns
0 mg past 30 days	25 9.03	17 8.59	8 10.53	
Between 1 and 150 mg in past 30 days	166 59.93	126 63.64	38 50.00	
Between 151 and 300 mg in past 30 days	26 9.39	19 9.60	7 9.21	
More than 300 mg in past 30 days	4 1.44	3 1.52	1 1.32	
Don't know/not sure	56 20.22	33 16.67	22 28.95	
Amount of CBD administered † ‡	275			ns
0 mg past 30 days	71 25.82	54 27.41	16 21.33	
Between 1 and 150 mg in past 30 days	119 43.27	88 44.67	30 40.00	
Between 151 and 300 mg in past 30 days	12 4.36	6 3.05	5 6.67	
More than 300 mg in past 30 days	2 0.73	1 0.51	1 1.33	
Don't know/not sure	71 25.82	48 24.37	23 30.67	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 11C: DPH Patient Drinking Marijuana Products by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Education		
	N %	< Bachelor's (N=2836)	≥ Bachelor's (N=3168)	p-value
Drank marijuana infused products in the past 30 days	6021			**
No	5736 95.27	2676 94.36	3043 96.05	
Yes	285 4.73	160 5.64	125 3.95	
Frequency of drinking marijuana infused products †	258			ns
Less than once per week	209 81.01	119 82.07	90 79.65	
More than once per week (but not as much as once per day)	26 10.08	12 8.28	14 12.39	
Once per day	15 5.81	10 6.90	5 4.42	
Multiple times per day	8 3.10	4 2.76	4 3.54	
Amount of THC administered † ‡	277			*
0 mg past 30 days	25 9.03	16 10.26	9 7.44	
Between 1 and 150 mg in past 30 days	166 59.93	85 54.49	81 66.94	
Between 151 and 300 mg in past 30 days	26 9.39	22 14.10	4 3.31	
More than 300 mg in past 30 days	4 1.44	2 1.28	2 1.65	
Don't know/not sure	56 20.22	31 19.87	25 20.66	
Amount of CBD administered † ‡	275			ns
0 mg past 30 days	71 25.82	41 26.62	30 24.79	
Between 1 and 150 mg in past 30 days	119 43.27	63 40.91	56 46.28	
Between 151 and 300 mg in past 30 days	12 4.36	10 6.49	2 1.65	
More than 300 mg in past 30 days	2 0.73	1 0.65	1 0.83	
Don't know/not sure	71 25.82	39 25.32	32 26.45	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Sublingual or Orally Administered Uptake Marijuana Products

Tables 12A, 12B, and 12C summarize results of survey responses pertaining to use of sublingual or orally administered uptake marijuana products, with comparisons by gender, age group, and educational attainment, respectively. 23% of respondents who reported using marijuana or marijuana products at least once in the past 30 days reported using sublingual or orally administered uptake marijuana products in the past 30 days. Using sublingual or orally administered uptake marijuana products was significantly higher among female respondents compared to male respondents (28% vs. 20%), respondents 51 years or older compared to younger respondents (26% vs. 22%) and respondents with a Bachelor's degree compared to respondents without a degree (25% vs. 22%).

Twenty-five percent of respondents who reported using sublingual or orally administered uptake marijuana products in the past 30 days reported using these products at least once per day, while 47% reported using these marijuana products less than once per week. A larger proportion of respondents over the age of 50 than younger respondents reported using sublingual or orally administered uptake marijuana products once per day (23% vs. 10%) and multiple times per day (10% vs. 6%).

All respondents who reported using sublingual or orally administered uptake marijuana products in the past 30 days were asked to indicate the amount of THC administered by using these products over the past 30 days. The amount of THC reported by respondents should be interpreted with caution, as almost 1 in 4 respondents did not know how much THC they administered through sublingual or orally administered uptake marijuana products. However, 54% of respondents reported administering between 1 and 150 mg of THC in the past 30 days through sublingual or orally administered uptake marijuana products.

All respondents who reported using sublingual or orally administered uptake marijuana products in the past 30 days were asked to indicate the amount of CBD administered by using these products over the past 30 days. The amount of CBD reported by respondents should be interpreted with caution, as 30% respondents did not know how much CBD they administered through sublingual or orally administered uptake marijuana products. However, 48% of respondents reported administering between 1 and 150 mg of THC in the past 30 days through sublingual or orally administered uptake marijuana products.

Table 12A: DPH Patient Survey Sublingual Marijuana Products by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Gender		
	N %	**Male** (N=3251)	**Female** (N=2672)	**p-value**
Used sublingual/orally administered uptake products in the past 30 days	6021			****
No	4608 76.53	2600 79.98	1934 72.38	
Yes	1413 23.47	651 20.02	738 27.62	
Frequency of using sublingual or orally administered uptake products †	1337			ns
Less than once per week	634 47.42	296 48.13	324 46.42	
More than once per week (but not as much as once per day)	370 27.67	170 27.64	194 27.79	
Once per day	218 16.31	96 15.61	119 17.05	
Multiple times per day	115 8.60	53 8.62	61 8.74	
Amount of THC administered † ‡	1359			**
0 mg past 30 days	182 13.39	62 9.90	115 16.22	
Between 1 and 150 mg in past 30 days	728 53.57	354 56.55	361 50.92	
Between 151 and 300 mg in past 30 days	81 5.96	45 7.19	35 4.94	
More than 300 mg in past 30 days	22 1.62	14 2.24	8 1.13	
Don't know/not sure	346 25.46	151 24.12	190 26.80	
Amount of CBD administered † ‡	1371			*
0 mg past 30 days	154 11.23	84 13.35	63 8.77	
Between 1 and 150 mg in past 30 days	664 48.43	294 46.74	358 49.86	
Between 151 and 300 mg in past 30 days	108 7.88	51 8.11	56 7.80	
More than 300 mg in past 30 days	36 2.63	21 3.34	15 2.09	
Don't know/not sure	409 29.83	179 28.46	226 31.48	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Oral Capsules/Tablets

Tables 13A, 13B, and 13C summarize results of survey responses pertaining to use of oral capsules or tablets, with comparisons by gender, age group, and educational attainment, respectively. 11% of respondents reported using oral capsules/tablets in the past 30 days to administer marijuana. There were no significant differences in the proportion of respondents who reported using oral capsules/tablets by gender, age, or education.

Twenty-four percent of respondents reported using oral capsules/tablets at least once per day, while 56% reported using these marijuana products less than once per week.

All respondents who reported using oral capsules/tablets in the past 30 days were asked to indicate the amount of THC administered by using these products over the past 30 days. The amount of THC reported by respondents should be interpreted with caution, as almost 1 in 5 respondents did not know how much THC they administered through oral capsules/tablets. However, 55% of respondents reported administering between 1 and 150 mg of THC in the past 30 days through oral capsules/tablets, and 15% reported administering 0 mg of THC. There were no significant differences the amount of THC administered by using capsules/tablets by gender, age, or education.

All respondents who reported using oral capsules/tablets in the past 30 days were asked to indicate the amount of CBD administered by using these products over the past 30 days. The amount of CBD reported by respondents should be interpreted with caution, as almost 1 in 4 respondents did not know how much CBD they administered through oral capsules/tablets. However, 47% of respondents reported administering between 1 and 150 mg of CBD in the past 30 days through oral capsules/tablets, and 16% reported administering 0 mg of CBD.

Table 13A: DPH Patient Survey Oral Capsules and Tables by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Gender Male (N=3251)	Female (N=2672)	p-value
Respondent used oral capsules/tablets (THC and/or CBD) in the past 30 days	6021			ns
No	5370 89.19	2898 89.14	2387 89.33	
Yes	651 10.81	353 10.86	285 10.67	
Frequency of using oral capsules/tablets in the past 30 days	595			ns
Less than once per week	331 55.63	177 55.66	147 55.47	
More than once per week (but not as much as once per day)	121 20.34	69 21.70	49 18.49	
Once per day	106 17.82	53 16.67	51 19.25	
Multiple times per day	37 6.22	19 5.97	18 6.79	
Amount of THC administered † ‡	623			ns
0 mg past 30 days	95 15.25	48 14.24	47 17.15	
Between 1 and 150 mg in past 30 days	345 55.38	187 55.49	151 55.11	
Between 151 and 300 mg in past 30 days	49 7.87	28 8.31	20 7.30	
More than 300 mg in past 30 days	15 2.41	12 3.56	2 0.73	
Don't know/not sure	119 19.1	62 18.40	54 19.71	
Amount of CBD administered † ‡	628			ns
0 mg past 30 days	103 16.40	57 16.76	45 16.30	
Between 1 and 150 mg in past 30 days	292 46.50	157 46.18	129 46.74	
Between 151 and 300 mg in past 30 days	56 8.92	27 7.94	29 10.51	
More than 300 mg in past 30 days	23 3.66	15 4.41	8 2.90	
Don't know/not sure	154 24.52	84 24.71	65 23.55	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 13B: DPH Patient Survey Oral Capsules and Tables by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Age Group		
	N %	**≤ 50 years** (N=3179)	**≥ 51 years** (N=2748)	**p-value**
Respondent used oral capsules/tablets (THC and/or CBD) in the past 30 days	6021			ns
No	5370 89.19	2822 88.77	2463 89.63	
Yes	651 10.81	357 11.23	285 10.37	
Frequency of using oral capsules/tablets in the past 30 days	595			**
Less than once per week	331 55.63	206 62.24	121 47.27	
More than once per week (but not as much as once per day)	121 20.34	59 17.82	60 23.44	
Once per day	106 17.82	49 14.80	55 21.48	
Multiple times per day	37 6.22	17 5.14	20 7.81	
Amount of THC administered † ‡	623			ns
0 mg past 30 days	95 15.25	51 14.83	44 16.24	
Between 1 and 150 mg in past 30 days	345 55.38	192 55.81	147 54.24	
Between 151 and 300 mg in past 30 days	49 7.87	34 9.88	14 5.17	
More than 300 mg in past 30 days	15 2.41	9 2.62	6 2.21	
Don't know/not sure	119 19.1	58 16.86	60 22.14	
Amount of CBD administered † ‡	628			*
0 mg past 30 days	103 16.40	61 17.68	39 14.18	
Between 1 and 150 mg in past 30 days	292 46.50	169 48.99	119 43.27	
Between 151 and 300 mg in past 30 days	56 8.92	34 9.86	22 8.00	
More than 300 mg in past 30 days	23 3.66	8 2.32	15 5.45	
Don't know/not sure	154 24.52	73 21.16	80 29.09	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 13C: DPH Patient Survey Oral Capsules and Tables by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Education < Bachelor's (N=2836)	≥ Bachelor's (N=3168)	p-value
Respondent used oral capsules/tablets (THC and/or CBD) in the past 30 days	6021			*
No	5370	2559	2795	
	89.19	90.23	88.23	
Yes	651	277	373	
	10.81	9.77	11.77	
Frequency of using oral capsules/tablets in the past 30 days	595			ns
Less than once per week	331	133	197	
	55.63	52.99	57.43	
More than once per week (but not as much as once per day)	121	49	72	
	20.34	19.52	20.99	
Once per day	106	46	60	
	17.82	18.33	17.49	
Multiple times per day	37	23	14	
	6.22	9.16	4.08	
Amount of THC administered † ‡	623			ns
0 mg past 30 days	95	37	58	
	15.25	14.02	16.20	
Between 1 and 150 mg in past 30 days	345	136	208	
	55.38	51.52	58.10	
Between 151 and 300 mg in past 30 days	49	29	20	
	7.87	10.98	5.59	
More than 300 mg in past 30 days	15	6	9	
	2.41	2.27	2.51	
Don't know/not sure	119	56	63	
	19.1	21.21	17.60	
Amount of CBD administered † ‡	628			ns
0 mg past 30 days	103	40	62	
	16.40	14.98	17.22	
Between 1 and 150 mg in past 30 days	292	122	170	
	46.50	45.69	47.22	
Between 151 and 300 mg in past 30 days	56	27	29	
	8.92	10.11	8.06	
More than 300 mg in past 30 days	23	11	12	
	3.66	4.12	3.33	
Don't know/not sure	154	67	87	
	24.52	25.09	24.17	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Topical Cannabis, Oil, Ointment, Lotion, Salve

Tables 14A, 14B, and 14C summarize results of survey responses pertaining to applying topical cannabis, oil, ointment, lotion, salve, or other marijuana products to the skin, with comparisons by gender, age group, and educational attainment, respectively. 27% of respondents who reported using marijuana at least once in the past 30 days reported applying topical cannabis to the skin in the past 30 days. A significantly larger proportion of female respondents compared to males report applying topical cannabis (35% vs. 20%).

Twenty-six percent of respondents who reported using topical cannabis in the past 30 days reported applying topical cannabis to the skin at least once per day, while 42% reported applying topical cannabis less than once per week. A larger proportion of respondents without a Bachelor's degree than respondents with a degree reported applying topical cannabis to the skin multiple times per day (14% vs. 7%), while a larger proportion of respondents with a Bachelor's degree than without reported applying topical cannabis to the skin less than once per week (46% vs. 36%).

All respondents who reported applying topical cannabis, oil, ointment, lotion, salve, etc. to the skin in the past 30 days were asked to indicate the amount of THC administered by using these products over the past 30 days. The amount of THC reported by respondents should be interpreted with caution, as more than 2 in 5 respondents did not know how much THC they administered through topical cannabis. However, 38% of respondents reported administering between 1 and 150 mg of THC in the past 30 days through topical cannabis, and 13% reported administering 0 mg of THC. A larger proportion of male respondents than female reported administering between 1 and 150 mg of topical cannabis to the skin (46% vs. 33%), while a larger proportion of females than males did not know how much THC they administered through topical cannabis (49% vs. 38%).

All respondents who reported applying topical cannabis, oil, ointment, lotion, salve, etc. to the skin in the past 30 days were asked to indicate the amount of CBD administered by using these products over the past 30 days. The amount of CBD reported by respondents should be interpreted with caution, as almost one half of all respondents did not know how much CBD they administered through topical cannabis. However, 42% of respondents reported administering between 1 and 150 mg of CBD in the past 30 days through topical cannabis.

Table 14A: DPH Patient Survey Topical Marijuana by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Gender Male (N=3251)	Female (N=2672)	p-value
Respondent applied topical marijuana to skin in the past 30 days	6021			****
No	4421	2613	1739	
	73.43	80.38	65.08	
Yes	1600	638	933	
	26.57	19.62	34.92	
Frequency of applying topical marijuana to skin	1513			***
Less than once per week	628	271	344	
	41.51	45.55	38.65	
More than once per week (but not as much as once per day)	494	195	293	
	32.65	32.77	32.92	
Once per day	229	88	136	
	15.14	14.79	15.28	
Multiple times per day	162	41	117	
	10.71	6.89	13.15	
Amount of THC administered † ‡	1554			****
0 mg past 30 days	205	71	130	
	13.19	11.45	14.35	
Between 1 and 150 mg in past 30 days	593	284	298	
	38.16	45.81	32.89	
Between 151 and 300 mg in past 30 days	57	27	28	
	3.67	4.35	3.09	
More than 300 mg in past 30 days	10	3	6	
	0.64	0.48	0.66	
Don't know/not sure	689	235	444	
	44.34	37.90	49.01	
Amount of CBD administered † ‡	1557			***
0 mg past 30 days	103	40	60	
	6.62	6.43	6.62	
Between 1 and 150 mg in past 30 days	656	299	344	
	42.13	48.07	37.93	
Between 151 and 300 mg in past 30 days	70	31	36	
	4.50	4.98	3.97	
More than 300 mg in past 30 days	10	3	7	
	0.64	0.48	0.77	
Don't know/not sure	718	249	460	
	46.11	40.03	50.72	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 14B: DPH Patient Survey Topical Marijuana by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Age Group ≤ 50 years (N=3179)	≥ 51 years (N=2748)	p-value
Respondent applied topical marijuana to skin in the past 30 days	6021			*
No	4421	2376	1978	
	73.43	74.74	71.98	
Yes	1600	803	770	
	26.57	25.26	28.02	
Frequency of applying topical marijuana to skin	1513			***
Less than once per week	628	355	261	
	41.51	46.65	35.80	
More than once per week (but not as much as once per day)	494	238	252	
	32.65	31.27	34.57	
Once per day	229	94	130	
	15.14	12.35	17.83	
Multiple times per day	162	74	86	
	10.71	9.72	11.80	
Amount of THC administered † ‡	1554			*
0 mg past 30 days	205	99	103	
	13.19	12.68	13.79	
Between 1 and 150 mg in past 30 days	593	323	259	
	38.16	41.36	34.67	
Between 151 and 300 mg in past 30 days	57	34	22	
	3.67	4.35	2.95	
More than 300 mg in past 30 days	10	6	4	
	0.64	0.77	0.54	
Don't know/not sure	689	319	359	
	44.34	40.85	48.06	
Amount of CBD administered † ‡	1557			***
0 mg past 30 days	103	52	50	
	6.62	6.68	6.65	
Between 1 and 150 mg in past 30 days	656	361	283	
	42.13	46.34	37.63	
Between 151 and 300 mg in past 30 days	70	41	28	
	4.50	5.26	3.72	
More than 300 mg in past 30 days	10	7	3	
	0.64	0.90	0.40	
Don't know/not sure	718	318	388	
	46.11	40.82	51.60	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 14C: DPH Patient Survey Topical Marijuana by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total	Education		
	N %	**< Bachelor's** (N=2836)	**≥ Bachelor's** (N=3168)	**p-value**
Respondent applied topical marijuana to skin in the past 30 days	6021			ns
No	4421	2075	2333	
	73.43	73.17	73.64	
Yes	1600	761	835	
	26.57	26.83	26.36	
Frequency of applying topical marijuana to skin	1513			****
Less than once per week	628	256	370	
	41.51	36.26	46.02	
More than once per week (but not as much	494	239	255	
as once per day)	32.65	33.85	31.72	
Once per day	229	109	120	
	15.14	15.44	14.93	
Multiple times per day	162	102	59	
	10.71	14.45	7.34	
Amount of THC administered † ‡	1554			***
0 mg past 30 days	205	86	119	
	13.19	11.72	14.57	
Between 1 and 150 mg in past 30 days	593	272	320	
	38.16	37.06	39.17	
Between 151 and 300 mg in past 30 days	57	43	13	
	3.67	5.86	1.59	
More than 300 mg in past 30 days	10	5	5	
	0.64	0.68	0.61	
Don't know/not sure	689	328	360	
	44.34	44.69	44.06	
Amount of CBD administered † ‡	1557			**
0 mg past 30 days	103	54	48	
	6.62	7.32	5.89	
Between 1 and 150 mg in past 30 days	656	296	359	
	42.13	40.11	44.05	
Between 151 and 300 mg in past 30 days	70	47	22	
	4.50	6.37	2.70	
More than 300 mg in past 30 days	10	6	4	
	0.64	0.81	0.49	
Don't know/not sure	718	335	382	
	46.11	45.39	46.87	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Rectal/Vaginal Cannabis

Tables 15A, 15B, and 15C summarize results of survey responses pertaining to using rectal/vaginal cannabis, with comparisons by gender, age group, and educational attainment, respectively. 1% of respondents who reported marijuana or marijuana product use at least once in the past 30 days reported using rectal/vaginal cannabis in the past 30 days. There were no significant differences in the proportion of respondents who reported use of rectal/vaginal cannabis by gender, age, or education.

Eighty-nine percent of respondents who reported using rectal/vaginal cannabis in the past 30 days reported using rectal/vaginal cannabis less than once per week. There were no significant differences in the frequency of rectal/vaginal cannabis use by gender, age, or education.

All respondents who reported using rectal/vaginal cannabis in the past 30 days were asked to indicate the amount of THC administered by using these products over the past 30 days. The amount of THC reported by respondents should be interpreted with caution, as almost 1 in 5 did not know how much THC they administered through rectal/vaginal cannabis. However, 70% of respondents reported administering between 1 and 150 mg of THC in the past 30 days through rectal/vaginal cannabis. There were no significant differences in the amount of THC administered by using rectal/vaginal cannabis by gender, age, or education.

All respondents who reported using rectal/vaginal cannabis in the past 30 days were asked to indicate the amount of CBD administered by using these products over the past 30 days. The amount of CBD reported by respondents should be interpreted with caution, as almost one third of all respondents did not know how much CBD they administered through rectal/vaginal cannabis. However, 39% of respondents reported administering between 1 and 150 mg of CBD in the past 30 days through rectal/vaginal cannabis, while 24% reported administering 0 mg. There were no significant differences in the amount of CBD administered by using rectal/vaginal cannabis by gender, age, or education.

Table 15A: DPH Patient Survey Rectal/Vaginal Marijuana by Gender (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Gender Male (N=3293)	Female (N=2720)	p-value
Respondent used rectal/vaginal cannabis in the past 30 days	6021			ns
No	5946 98.75	3219 99.02	2633 98.54	
Yes	75 1.25	32 0.98	39 1.46	
Frequency of using rectal/vaginal cannabis in the past 30 days	66			ns
Less than once per week	58 87.88	23 82.14	33 91.67	
More than once per week (but not as much as once per day)	3 4.55	1 3.57	2 5.56	
Once per day	2 3.03	1 3.57	1 2.78	
Multiple times per day	3 4.55	3 10.71	0 0.00	
Amount of THC administered † ‡	69			ns
0 mg past 30 days	3 4.35	1 3.45	1 2.70	
Between 1 and 150 mg in past 30 days	48 69.57	19 65.52	27 72.97	
Between 151 and 300 mg in past 30 days	4 5.80	3 10.34	1 2.70	
More than 300 mg in past 30 days	1 1.45	1 3.45	0 0.00	
Don't know/not sure	13 18.84	5 17.24	8 21.62	
Amount of CBD administered † ‡	70			ns
0 mg past 30 days	17 24.29	4 13.79	12 31.58	
Between 1 and 150 mg in past 30 days	27 38.57	12 41.38	13 34.21	
Between 151 and 300 mg in past 30 days	3 4.29	2 6.90	1 2.63	
More than 300 mg in past 30 days	0 0.00	0 0.00	0 0.00	
Don't know/not sure	23 32.86	11 37.93	12 31.58	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 15B: DPH Patient Survey Rectal/Vaginal Marijuana by Age Group (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Age Group ≤ 50 years (N=3224)	≥ 51 years (N=2793)	p-value
Respondent used rectal/vaginal cannabis in the past 30 days	6021			ns
No	5946 98.75	3131 98.49	2722 99.05	
Yes	75 1.25	48 1.51	26 0.95	
Frequency of using rectal/vaginal cannabis in the past 30 days	66			ns
Less than once per week	58 87.88	41 95.35	17 73.91	
More than once per week (but not as much as once per day)	3 4.55	1 2.33	2 8.70	
Once per day	2 3.03	0 0.00	2 8.70	
Multiple times per day	3 4.55	1 2.33	2 8.70	
Amount of THC administered † ‡	69			ns
0 mg past 30 days	3 4.35	2 4.44	1 4.17	
Between 1 and 150 mg in past 30 days	48 69.57	33 73.33	15 62.50	
Between 151 and 300 mg in past 30 days	4 5.80	2 4.44	2 8.33	
More than 300 mg in past 30 days	1 1.45	0 0.00	1 4.17	
Don't know/not sure	13 18.84	8 17.78	5 20.83	
Amount of CBD administered † ‡	70			ns
0 mg past 30 days	17 24.29	11 24.44	6 24.00	
Between 1 and 150 mg in past 30 days	27 38.57	18 40.00	9 36.00	
Between 151 and 300 mg in past 30 days	3 4.29	3 6.67	0 0.00	
More than 300 mg in past 30 days	0 0.00	0 0.00	0 0.00	
Don't know/not sure	23 32.86	13 28.89	10 40.00	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 15C: DPH Patient Survey Rectal/Vaginal Marijuana by Education (Among 6,111 Respondents who Used Marijuana in Past 30 Days)

	Total N %	Education < Bachelor's (N=2871)	≥ Bachelor's (N=3223)	p-value
Respondent used rectal/vaginal cannabis in the past 30 days	6021			ns
No	5946 98.75	2802 98.80	3127 98.71	
Yes	75 1.25	34 1.20	41 1.29	
Frequency of using rectal/vaginal cannabis in the past 30 days	66			ns
Less than once per week	58 87.88	25 83.33	33 91.67	
More than once per week (but not as much as once per day)	3 4.55	3 10.00	0 0.00	
Once per day	2 3.03	1 3.33	1 2.78	
Multiple times per day	3 4.55	1 3.33	2 5.56	
Amount of THC administered † ‡	69			ns
0 mg past 30 days	3 4.35	1 3.33	2 5.13	
Between 1 and 150 mg in past 30 days	48 69.57	22 73.33	26 66.67	
Between 151 and 300 mg in past 30 days	4 5.80	0 0.00	4 10.26	
More than 300 mg in past 30 days	1 1.45	0 0.00	1 2.56	
Don't know/not sure	13 18.84	7 23.33	6 15.38	
Amount of CBD administered † ‡	70			ns
0 mg past 30 days	17 24.29	5 16.67	12 30.00	
Between 1 and 150 mg in past 30 days	27 38.57	13 43.33	14 35.00	
Between 151 and 300 mg in past 30 days	3 4.29	2 6.67	1 2.50	
More than 300 mg in past 30 days	0 0.00	0 0.00	0 0.00	
Don't know/not sure	23 32.86	10 33.33	13 32.50	

† *Among respondents reporting using vaporized marijuana concentrate in the past 30 days*
‡ *Total monthly amount consumed*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Perceptions of Medical Marijuana Use

All respondents, regardless of their use of marijuana in the past 30 days, were asked to report on various perceptions and behavior related to medical use of marijuana. Results are summarized in *Tables 16A, 16B, and 16C*, with comparisons by gender, age group, and educational attainment, respectively.

Sixty-six percent of survey respondents reported using marijuana or marijuana products for medical purposes for at least a year, with 20% reporting use for over 3 years. 7% of respondents reported medical use of marijuana or marijuana products for 3 months or less. A larger proportion of male respondents than female reported medical use for at least 3 years (21% vs. 16%), while a larger proportion of respondents under the age of 51 compared to older respondents reported medical use for at least 3 years (22% vs. 16%). Finally, a larger proportion of respondents without a Bachelor's degree than with reported medical use for at least 3 years (22% vs. 17%).

Ninety-four percent of survey respondents reported feeling safe or very safe when buying medical marijuana products at a licensed dispensary, while 5% reported feeling very unsafe. A larger proportion of respondents over the age of 50 than younger respondents reported felling very unsafe (7% vs. 4%), while a larger proportion of younger respondents than older reported feeling very safe (89% vs. 86%). A larger proportion of respondents without a Bachelor's degree than with a degree reported feeling very unsafe (7% vs. 4%), while a larger proportion of respondents with a Bachelor's degree than without reported feeling very safe (90% vs. 85%).
Sixty-six percent of survey respondents reported somewhat high or very high knowledge of products when selecting products for medical use, while 7% reported somewhat low or very low knowledge. A larger proportion of male respondents than female reported very high knowledge (42% vs. 32%), while a larger proportion of female respondents than male reported average knowledge (31% vs. 23%). A larger proportion of respondents under the age of 51 than older respondents report very high knowledge (43% vs 32%), while a larger proportion of older respondents than younger report average knowledge (29% vs. 24%).

Eighty-nine percent of survey respondents indicated that they had somewhat high or very high confidence that they were receiving safe, uncontaminated products at licensed dispensaries, while less than 2% reported that they had somewhat low or very low confidence. A larger proportion of respondents younger than 51 compared to older respondents reported very high confidence (71% vs. 67%), while a larger proportion of older respondents reported average confidence (11% vs. 8%). A larger proportion of respondents with a Bachelor's degree than without a degree reported very high confidence in receiving safe, uncontaminated products (71% vs. 68%).

Ninety-one percent of survey respondents reported that marijuana use has been effective or very effective in treating their medical condition, while 2% reported that marijuana use has had little effect or no effect at all. A larger proportion of male respondents than female reported that marijuana use has been effective (27% vs. 24%).

A larger proportion of respondents less than 51 years old than older respondents reported that marijuana use has been very effective (72% vs. 58%), while a larger proportion of older respondents than younger reported that marijuana use has been effective (30% vs. 22%) or somewhat effective (10% vs. 5%).

Table 16A: DPH Patient Survey Perceptions of Medical Use of Marijuana by Gender (Among All 6,934 Respondents)

	Total	Gender		
	N %	**Male** (N=3732)	**Female** (N=3056)	**p-value**
Length of time using marijuana or marijuana products for medical purposes	6574			****
0-3 months	466 7.09	223 6.31	238 8.12	
3-6 months	675 10.27	341 9.65	324 11.05	
6-12 months	1124 17.10	584 16.53	522 17.80	
1-3 years	3051 46.41	1633 46.22	1365 46.56	
3+ years	1258 19.14	752 21.29	483 16.47	
When you buy medical marijuana at a licensed dispensary, how do you feel about your personal safety?	6552			ns
Very unsafe	340 5.19	186 5.28	150 5.13	
Somewhat unsafe	61 0.93	34 0.97	26 0.89	
Somewhat safe	408 6.23	221 6.28	182 6.22	
Very safe	5743 87.65	3079 87.47	2566 87.76	
When selecting a marijuana product for your medical use, how would you rate your current knowledge of the recommended product based on information provided by your certified practitioner?	6461			****
Very low	159 2.46	65 1.87	90 3.13	
Somewhat low	306 4.74	138 3.97	166 5.77	
Average	1734 26.84	796 22.88	906 31.49	
Somewhat high	1825 28.25	1015 29.18	784 27.25	
Very high	2437 37.72	1465 42.11	931 32.36	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

(Continued) Table 16A: DPH Patient Survey Perceptions of Medical Use of Marijuana by Gender (Among All 6,934 Respondents)

	Total N %	Gender		
		Male (N=3732)	Female (N=3056)	p-value
When purchasing marijuana or marijuana products at a licensed dispensary, how confident do you feel that you are receiving a safe, uncontaminated product?	6538			ns
Very low confidence	41	22	17	
	0.63	0.63	0.58	
Low confidence	79	45	33	
	1.21	1.28	1.13	
Average confidence	613	322	280	
	9.38	9.15	9.62	
Somewhat high confidence	1266	727	520	
	19.36	20.65	17.86	
Very high confidence	4539	2404	2062	
	69.42	68.30	70.81	
How effective do you feel marijuana or marijuana products have been in treating the medical condition for which you are using it?	6551			****
Not effective at all	40	16	23	
	0.61	0.45	0.79	
A little effective	92	37	55	
	1.40	1.05	1.88	
Somewhat effective	465	222	235	
	7.10	6.31	8.04	
Effective	1678	960	693	
	25.61	27.27	23.70	
Very effective	4276	2285	1918	
	65.27	64.91	65.60	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

Table 16B: DPH Patient Survey Perceptions of Medical Use of Marijuana by Age Group (Among All 6,934 Respondents)

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
Length of time using marijuana or marijuana products for medical purposes	6574			****
0-3 months	466	232	225	
	7.09	6.79	7.40	
3-6 months	675	365	301	
	10.27	10.68	9.90	
6-12 months	1124	578	523	
	17.10	16.91	17.20	
1-3 years	3051	1498	1499	
	46.41	43.83	49.29	
3+ years	1258	745	493	
	19.14	21.80	16.21	
When you buy medical marijuana at a licensed dispensary, how do you feel about your personal safety?	6552			****
Very unsafe	340	122	207	
	5.19	3.59	6.81	
Somewhat unsafe	61	34	26	
	0.93	1.00	0.86	
Somewhat safe	408	220	183	
	6.23	6.47	6.02	
Very safe	5743	3023	2623	
	87.65	88.94	86.31	
When selecting a marijuana product for your medical use, how would you rate your current knowledge of the recommended product based on information provided by your certified practitioner?	6461			****
Very low	159	58	98	
	2.46	1.74	3.26	
Somewhat low	306	109	188	
	4.74	3.26	6.25	
Average	1734	810	885	
	26.84	24.25	29.43	
Somewhat high	1825	918	879	
	28.25	27.49	29.23	
Very high	2437	1445	957	
	37.72	43.26	31.83	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 16B: DPH Patient Survey Perceptions of Medical Use of Marijuana by Gender (Among All 6,934 Respondents)

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
When purchasing marijuana or marijuana products at a licensed dispensary, how confident do you feel that you are receiving a safe, uncontaminated product?	6538			****
Very low confidence	41	25	14	
	0.63	0.73	0.46	
Low confidence	79	51	27	
	1.21	1.50	0.89	
Average confidence	613	261	342	
	9.38	7.67	11.33	
Somewhat high confidence	1266	641	610	
	19.36	18.84	20.21	
Very high confidence	4539	2425	2026	
	69.42	71.26	67.11	
How effective do you feel marijuana or marijuana products have been in treating the medical condition for which you are using it?	6551			****
Not effective at all	40	7	32	
	0.61	0.21	1.06	
A little effective	92	39	49	
	1.40	1.15	1.62	
Somewhat effective	465	159	296	
	7.10	4.67	9.77	
Effective	1678	762	896	
	25.61	22.37	29.57	
Very effective	4276	2439	1757	
	65.27	71.61	57.99	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

Table 16C: DPH Patient Survey Perceptions of Medical Use of Marijuana by Education (Among All 6,934 Respondents)

	Total N %	Education		
		< Bachelor's (N=3282)	≥ Bachelor's (N=3595)	p-value
Length of time using marijuana or marijuana products for medical purposes	6574			****
0-3 months	466	200	263	
	7.09	6.40	7.67	
3-6 months	675	304	368	
	10.27	9.73	10.73	
6-12 months	1124	505	619	
	17.10	16.16	18.04	
1-3 years	3051	1432	1610	
	46.41	45.82	46.93	
3+ years	1258	684	571	
	19.14	21.89	16.64	
When you buy medical marijuana at a licensed dispensary, how do you feel about your personal safety?	6552			****
Very unsafe	340	210	129	
	5.19	6.76	3.76	
Somewhat unsafe	61	33	27	
	0.93	1.06	0.79	
Somewhat safe	408	223	183	
	6.23	7.18	5.34	
Very safe	5743	2639	3091	
	87.65	84.99	90.12	
When selecting a marijuana product for your medical use, how would you rate your current knowledge of the recommended product based on information provided by your certified practitioner?	6461			***
Very low	159	66	91	
	2.46	2.15	2.69	
Somewhat low	306	145	161	
	4.74	4.73	4.76	
Average	1734	839	889	
	26.84	27.38	26.31	
Somewhat high	1825	791	1029	
	28.25	25.82	30.45	
Very high	2437	1223	1209	
	37.72	39.92	35.78	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

(Continued) Table 16C: DPH Patient Survey Perceptions of Medical Use of Marijuana by Education (Among All 6,934 Respondents)

	Total N %	Education < Bachelor's (N=3282)	Education ≥ Bachelor's (N=3595)	p-value
When purchasing marijuana or marijuana products at a licensed dispensary, how confident do you feel that you are receiving a safe, uncontaminated product?	6538			****
Very low confidence	41	27	13	
	0.63	0.87	0.38	
Low confidence	79	39	40	
	1.21	1.26	1.17	
Average confidence	613	348	264	
	9.38	11.20	7.73	
Somewhat high confidence	1266	590	672	
	19.36	18.99	19.68	
Very high confidence	4539	2103	2425	
	69.42	67.69	71.03	
How effective do you feel marijuana or marijuana products have been in treating the medical condition for which you are using it?	6551			***
Not effective at all	40	20	20	
	0.61	0.64	0.58	
A little effective	92	34	58	
	1.40	1.09	1.69	
Somewhat effective	465	193	270	
	7.10	6.21	7.89	
Effective	1678	756	919	
	25.61	24.31	26.85	
Very effective	4276	2107	2156	
	65.27	67.75	62.99	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

Driving Issues Related to Marijuana Use

All survey respondents were asked to report on their driving behaviors related to marijuana use. Results are summarized in *Tables 17A, 17B, and 17C*, with comparisons by gender, age group, and educational attainment, respectively.

Ten percent of survey respondents indicated that in the past 30 days they had driven or operated a car or other motor vehicle while under the influence of marijuana or marijuana products. A larger proportion of respondents without a Bachelor's degree than with a degree reported driving while impaired (11% vs. 10%).

Eleven percent of survey respondents indicated that in the past 30 days they had ridden as a passenger in a car or other motor vehicle while the driver was under the influence of marijuana or marijuana products. A significantly larger proportion of respondents under age 51 compared to over 50 (14% vs. 7%) reported riding as a passenger with an impaired driver in the past 30 days, as did a larger proportion of respondents without a Bachelor's degree compared to with a degree (13% vs. 9%).

Table 17A: DPH Patient Survey Driving Issued Related to Marijuana Use by Gender (Among All 6,934 Respondents)

	Total **N** **%**	**Gender**		
		Male (N=3732)	**Female** (N=3056)	**p-value**
During the past 30 days, how many times did you <u>drive/operate</u> a car or other motor vehicle when you were under the influence of (impaired from) marijuana or marijuana products?	6311			*
0 times	5472 86.71	2900 85.88	2489 87.73	
At least once	656 10.39	383 11.34	262 9.24	
Don't know/not sure	183 2.90	94 2.78	86 3.03	
During the past 30 days, how many times did you <u>ride as a passenger</u> in a car or other motor vehicle when the driver was under the influence of (impaired from) marijuana or marijuana products?	6414			ns
0 times	5486 85.53	2939 85.56	2463 85.58	
At least once	681 10.62	368 10.71	303 10.53	
Don't know/not sure	247 3.85	128 3.73	112 3.89	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

Table 17B: DPH Patient Survey Driving Issued Related to Marijuana Use by Age Group (Among All 6,934 Respondents)

	Total N %	Age Group		
		≤ 50 years (N=3584)	**≥ 51 years** (N=3188)	**p-value**
During the past 30 days, how many times did you drive/operate a car or other motor vehicle when you were under the influence of (impaired from) marijuana or marijuana products?	6311			**
0 times	5472 86.71	2766 85.27	2612 88.30	
At least once	656 10.39	377 11.62	270 9.13	
Don't know/not sure	183 2.90	101 3.11	76 2.57	
During the past 30 days, how many times did you ride as a passenger in a car or other motor vehicle when the driver was under the influence of (impaired from) marijuana or marijuana products?	6414			****
0 times	5486 85.53	2687 81.45	2700 89.91	
At least once	681 10.62	465 14.10	207 6.89	
Don't know/not sure	247 3.85	147 4.46	96 3.20	
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*				

Table 17C: DPH Patient Survey Driving Issued Related to Marijuana Use by Education (Among All 6,934 Respondents)

	Total N %	Education < Bachelor's (N=3282)	≥ Bachelor's (N=3595)	p-value
During the past 30 days, how many times did you <u>drive/operate</u> a car or other motor vehicle when you were under the influence of (impaired from) marijuana or marijuana products?	6311			****
0 times	5472 86.71	2548 84.96	2912 88.35	
At least once	656 10.39	336 11.20	317 9.62	
Don’t know/not sure	183 2.90	115 3.83	67 2.03	
During the past 30 days, how many times did you <u>ride as a passenger</u> in a car or other motor vehicle when the driver was under the influence of (impaired from) marijuana or marijuana products?	6414			****
0 times	5486 85.53	2505 82.35	2968 88.44	
At least once	681 10.62	393 12.92	286 8.52	
Don’t know/not sure	247 3.85	144 4.73	102 3.04	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Other Issues Related to Marijuana Use

All respondents were asked a series of questions pertaining to outcomes and consequences related to marijuana use, as well as other issues related to marijuana use. Results are summarized in *Tables 18A, 18B, and 18C*, with comparisons by gender, age group, and educational attainment, respectively.

All survey respondents were asked to choose from a list negative outcomes/consequences related to their marijuana use. 83% of respondents reported experiencing no negative outcomes related to marijuana use. A significantly larger proportion of respondents over the age of 51 than under reported no negative outcomes related to marijuana use (86% vs 80%). A significantly larger proportion of respondents under the age of 51 than over reported negative occupational/job-related issues related to marijuana use (1% vs. 0%). A significantly larger proportion of respondents with a Bachelor’s degree than without a degree reported negative changes in cognition related to marijuana use (8% vs. 5%).

All survey respondents were asked to choose from a list of positive outcomes/consequences related to their marijuana use. 78% reported positive changes in mood or mental health, 67% reported improved physical health, 30% reported positive changes in cognition, 41% reported positive changes in social relationships, and 3% reported no positive outcomes or consequences. A significantly larger proportion of respondents younger than 51 years old reported positive changes in mood or mental health (87% vs. 70%), positive changes in cognition (37% vs. 22%) and positive changes in social relationships (52% vs. 29%). A larger proportion of respondents older than 50 years old reported no positive outcomes (4% vs. 2%). A significantly larger proportion of respondents without a Bachelor's degree than with a degree reported positive changes in cognition (35% vs. 25%) and positive changes in social relationships (46% vs. 38%).

Less than 1% of survey respondents indicated being treated in an emergency room or urgent care facility for reasons related to marijuana use. 14% of respondents who have used marijuana or marijuana products for medical purposes for at least 6 months reported needing to consume larger amounts of marijuana in the past 12 months in order to feel the same effects. A significantly larger proportion of respondents under the age of 51 than older respondents reported needing to consume larger amounts (19% vs. 8%).

Eighteen percent of respondents who have used marijuana or marijuana products for medical purposes for at least 6 months reported trying to cut down on their use of marijuana in the past 12 months. A significantly larger proportion of male respondents than female reported trying to cut down on their use of marijuana (20% vs. 16%), and a larger proportion of respondents under the age of 51 than older respondents reported trying to cut down their use of marijuana (23% vs. 13%). 9% of respondents have used marijuana or marijuana products for medical purposes for at least 6 months and who indicated trying to cut down on their marijuana use in the past 12 months reported feeling sick or experiencing withdrawal symptoms because of reduced marijuana use. There were no significant differences by gender, age, or education.

Table 18A: DPH Patient Survey Other Issues Related to Marijuana Use by Gender (Among All 6,934 Respondents)

	Total N %	Gender		
		Male (N=3732)	**Female** (N=3056)	**p-value**
Have you noticed any of the following *negative* outcomes/consequences related to your marijuana use?	6572			
Negative changes in mood or mental health	141 2.15	65 1.84	71 2.42	ns
Reduction in physical health	57 0.87	27 0.76	28 0.96	ns
Negative changes in cognition	435 6.62	223 6.32	191 6.52	ns
Negative changes in social relationships	75 1.14	52 1.47	22 0.75	**
Occupation/job-related issues	58 0.88	43 1.22	14 0.48	**
Other outcomes/consequences	370 5.63	178 5.04	183 6.24	*
No negative outcomes/consequences	5452 82.96	2952 83.63	2426 82.77	ns
Have you noticed any of the following *positive* outcomes/consequences related to your marijuana use?	6572			
Positive changes in mood or mental health	5158 78.48	2804 79.43	2261 77.14	*
Improved physical health	4435 67.48	2354 66.69	2010 68.58	ns
Positive changes in cognition	1979 30.11	1109 31.42	823 28.08	**
Positive changes in social relationships	2717 41.34	1509 42.75	1145 39.07	**
Other outcomes/consequences	1005 15.29	492 13.94	487 16.62	**
No positive outcomes/consequences	168 2.56	84 2.38	82 2.80	ns

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 18A: DPH Patient Survey Other Issues Related to Marijuana Use by Gender (Among the 5433 Respondents who have Used Medical Use of Marijuana or Marijuana Products for at least 6 Months)

	Total N %	Gender		
		Male (N=3732)	**Female** (N=3056)	**p-value**
Treated in an emergency room or urgent care facility for any reason related to marijuana or marijuana product use?	6499			ns
0 times	6492 99.89	3486 99.89	2901 99.90	
At least once	7 0.11	4 0.11	3 0.10	
In the past 12 months, have you needed to consume larger amounts of marijuana or marijuana products in order to feel the same effects?	5011			ns
No	4313 86.07	2381 86.55	1864 85.62	
Yes	698 13.93	370 13.45	313 14.38	
In the past 12 months, have you tried to cut down on your marijuana or marijuana product use?	5010			****
No	4094 81.72	2187 79.76	1847 84.18	
Yes	916 18.28	555 20.24	347 15.82	
In the past 12 months, have you felt sick or had withdrawal symptoms because you stopped or cut down on your marijuana or marijuana product use? †	863			ns
No	786 91.08	472 90.08	300 92.59	
Yes	77 8.92	52 9.92	24 7.41	

† *Among respondents who reported trying to cut down on marijuana or marijuana product use in the past 12 months*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 18B: DPH Patient Survey Other Issues Related to Marijuana Use by Age Group (Among All 6,934 Respondents)

	Total N %	Age Group ≤ 50 years (N=3584)	 ≥ 51 years (N=3188)	 p-value
Have you noticed any of the following *negative* outcomes/consequences related to your marijuana use?	6572			
Negative changes in mood or mental health	141 2.15	92 2.70	48 1.58	**
Reduction in physical health	57 0.87	40 1.17	17 0.56	**
Negative changes in cognition	435 6.62	257 7.54	174 5.71	**
Negative changes in social relationships	75 1.14	45 1.32	30 0.98	ns
Occupation/job-related issues	58 0.88	45 1.32	12 0.39	****
Other outcomes/consequences	370 5.63	208 6.10	156 5.12	ns
No negative outcomes/consequences	5452 82.96	2741 80.40	2611 85.72	****
Have you noticed any of the following *positive* outcomes/consequences related to your marijuana use?	6572			
Positive changes in mood or mental health	5158 78.48	2955 86.68	2123 69.70	****
Improved physical health	4435 67.48	2330 68.35	2033 66.74	ns
Positive changes in cognition	1979 30.11	1266 37.14	678 22.26	****
Positive changes in social relationships	2717 41.34	1784 52.33	891 29.25	****
Other outcomes/consequences	1005 15.29	441 12.94	551 18.09	****
No positive outcomes/consequences	168 2.56	53 1.55	112 3.68	****

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 18B: DPH Patient Survey Other Issues Related to Marijuana Use by Age Group (Among the 5433 Respondents who have Used Medical Use of Marijuana or Marijuana Products for at least 6 Months)

	Total N %	Age Group		
		≤ 50 years (N=3584)	**≥ 51 years** (N=3188)	**p-value**
Treated in an emergency room or urgent care facility for any reason related to marijuana or marijuana product use?	6499			ns
0 times	6492 99.89	3363 99.88	3016 99.90	
At least once	7 0.11	4 0.12	3 0.10	
In the past 12 months, have you needed to consume larger amounts of marijuana or marijuana products in order to feel the same effects?	5011			****
No	4313 86.07	2097 81.09	2141 91.65	
Yes	698 13.93	489 18.91	195 8.35	
In the past 12 months, have you tried to cut down on your marijuana or marijuana product use?	5010			****
No	4094 81.72	1990 77.04	2030 86.83	
Yes	916 18.28	593 22.96	308 13.17	
In the past 12 months, have you felt sick or had withdrawal symptoms because you stopped or cut down on your marijuana or marijuana product use? †	863			ns
No	786 91.08	499 89.75	270 93.10	
Yes	77 8.92	57 10.25	20 6.90	

† *Among respondents who reported trying to cut down on marijuana or marijuana product use in the past 12 months*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 18C: DPH Patient Survey Other Issues Related to Marijuana Use by Education (Among All 6,934 Respondents)

	Total N %	Education < Bachelor's (N=3282)	≥ Bachelor's (N=3595)	p-value
Have you noticed any of the following *negative* outcomes/consequences related to your marijuana use?	6572			
Negative changes in mood or mental health	141	65	75	ns
	2.15	2.08	2.18	
Reduction in physical health	57	28	29	ns
	0.87	0.90	0.84	
Negative changes in cognition	435	163	271	****
	6.62	5.23	7.89	
Negative changes in social relationships	75	38	37	ns
	1.14	1.22	1.08	
Occupation/job-related issues	58	38	19	**
	0.88	1.22	0.55	
Other outcomes/consequences	370	143	226	***
	5.63	4.58	6.58	
No negative outcomes/consequences	5452	2640	2799	***
	82.96	84.64	81.51	
Have you noticed any of the following *positive* outcomes/consequences related to your marijuana use?	6572			
Positive changes in mood or mental health	5158	2488	2656	*
	78.48	79.77	77.34	
Improved physical health	4435	2180	2246	***
	67.48	69.89	65.40	
Positive changes in cognition	1979	1101	872	****
	30.11	35.30	25.39	
Positive changes in social relationships	2717	1420	1290	****
	41.34	45.53	37.57	
Other outcomes/consequences	1005	430	567	**
	15.29	13.79	16.51	
No positive outcomes/consequences	168	78	90	ns
	2.56	2.50	2.62	

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 18C: DPH Patient Survey Other Issues Related to Marijuana Use by Education (Among the 5433 Respondents who have Used Medical Use of Marijuana or Marijuana Products for at least 6 Months)

	Total N %	Education		
		< Bachelor's (N=3282)	**≥ Bachelor's** (N=3595)	**p-value**
Treated in an emergency room or urgent care facility for any reason related to marijuana or marijuana product use?	6499			**
0 times	6492	3077	3399	
	99.89	99.77	100.00	
At least once	7	7	0	
	0.11	0.23	0.00	
In the past 12 months, have you needed to consume larger amounts of marijuana or marijuana products in order to feel the same effects?	5011			ns
No	4313	2065	2240	
	86.07	85.12	86.96	
Yes	698	361	336	
	13.93	14.88	13.04	
In the past 12 months, have you tried to cut down on your marijuana or marijuana product use?	5010			*
No	4094	1930	2156	
	81.72	80.32	82.99	
Yes	916	473	442	
	18.28	19.68	17.01	
In the past 12 months, have you felt sick or had withdrawal symptoms because you stopped or cut down on your marijuana or marijuana product use? †	863			ns
No	786	406	377	
	91.08	90.83	91.28	
Yes	77	41	36	
	8.92	9.17	8.72	

† *Among respondents who reported trying to cut down on marijuana or marijuana product use in the past 12 months*

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Alcohol Consumption

All respondents were asked to report on their alcohol consumption in the past 30 days and other related behaviors. Results are summarized in *Tables 19A, 19B, and 19C*, with comparisons by gender, age group, and educational attainment, respectively.
Forty-one percent of survey respondents reported no days in the past 30 days in which they consumed an alcoholic beverage, 42% reported consuming alcohol between 1 and 10 days, and 17% reported consuming alcohol more than 10 days in the past 30. A larger proportion of respondents over the age of 50 than younger respondents reported consuming no alcoholic beverages in the past 30 days (43% vs. 39%) and consuming alcohol for at least 21 days out of the past 30 (10% vs. 4%). A larger proportion of respondents under the age of 51 than older respondents reported consuming an alcoholic beverage between 1 and 10 days out of the past 30 (47% vs. 36%). A larger proportion of respondents without a Bachelor's degree than respondents with a degree reported consuming no alcoholic beverages in the past 30 days (53% vs. 31%), while a larger proportion of respondents with a Bachelor's degree than respondents without a degree reported consuming an alcoholic beverage between 1 and 10 days out of the past 30 (47% vs. 36%), between 11 and 20 days out of the past 30 (14% vs. 6%), and over 21 days out of the past 30 (8% vs. 5%).

Fifty-one percent of survey respondents reported spending $0 on alcohol in the past 30 days, 42% of respondents reported spending between $1 and $100, and 6% reported spending more than $100. A larger proportion of females than males reported spending $0 (54% vs. 49%), and a larger proportion of males than females reported spending more than $100 (8% vs. 4%). A larger proportion of respondents over the age of 51 than under reported spending $0 on alcohol in the last 30 days (54% vs. 48%), while a larger proportion of younger respondents reported spending between $1 and $100 (44% vs. 41%). A larger proportion of respondents without a Bachelor's degree than with a degree reported spending $0 on alcohol in the past 30 days (63% vs. 41%), while a larger proportion of respondents with a degree reported spending between $1 and $100 (50% vs. 35%), between $101 and $200 (7% vs. 2%) and over $200 (3% vs. 1%).

Ninety-four percent of respondents who reported having at least one alcoholic beverage in the past 30 days reported that they did not drive while under the influence of alcohol in the last 30 days, while 6% reported that they had. There were no significant differences in the proportion of respondents driving under the influence of alcohol by gender, age, or education. 7% of survey respondents reported riding as a passenger in a vehicle while the driver was under the influence in the past 30 days.

Only 0.1% of survey respondents indicated being treated in an emergency room or urgent care facility for reasons related to alcohol use in the past 30 days. There were no significant differences in the proportion of respondents treated in an emergency room or urgent care facility for any reason related to alcohol use by gender, age, or education.

Table 19A: DPH Patient Survey Alcohol Consumption by Gender (Among All 6,934 Respondents)

	Total N %	Gender		
		Male (N=3732)	**Female** (N=3056)	**p-value**
Number of days respondent consumed an alcoholic beverage in past 30 days	6252			***
0 days	2569	1376	1146	
	41.09	41.15	40.84	
1-10 days	2609	1337	1233	
	41.73	39.98	43.94	
11-20 days	656	389	253	
	10.49	11.63	9.02	
21-30 days	418	242	174	
	6.69	7.24	6.20	
Money spent on alcohol in past 30 days	5328			****
$0	2727	1409	1267	
	51.18	48.86	53.71	
$1 to $100	2260	1234	996	
	42.42	42.79	42.22	
$101 to $200	240	167	70	
	4.50	5.79	2.97	
$201 or more	101	74	26	
	1.90	2.57	1.10	
Drove/operated motor vehicle while under the influence of alcohol †	3211			ns
No	3016	1579	1392	
	93.93	93.32	94.76	
Yes	182	104	73	
	5.67	6.15	4.97	
Don't know/not sure	13	9	4	
	0.40	0.53	0.27	
Rode as a passenger in motor vehicle when driver under influence of alcohol	6343			**
No	5901	3188	2621	
	93.03	93.85	92.03	
Yes	442	209	227	
	6.97	6.15	7.97	
Treated in emergency room for any reason related to alcohol use	6461			ns
No	6454	3459	2890	
	99.89	99.86	99.93	
Yes	7	5	2	
	0.11	0.14	0.07	

† *Among respondents indicating consuming at least one drink of any alcoholic beverage in the past 30 days*

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 19B: DPH Patient Survey Alcohol Consumption by Age Group (Among All 6,934 Respondents)

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
Number of days respondent consumed an alcoholic beverage in past 30 days	6252			****
0 days	2569	1267	1251	
	41.09	39.19	42.97	
1-10 days	2609	1509	1056	
	41.73	46.67	36.28	
11-20 days	656	332	318	
	10.49	10.27	10.92	
21-30 days	418	125	286	
	6.69	3.87	9.82	
Money spent on alcohol in past 30 days	5328			****
$0	2727	1338	1334	
	51.18	48.44	53.79	
$1 to $100	2260	1206	1024	
	42.42	43.66	41.29	
$101 to $200	240	150	89	
	4.50	5.43	3.59	
$201 or more	101	68	33	
	1.90	2.46	1.33	
Drove/operated motor vehicle while under the influence of alcohol †	3211			ns
No	3016	1703	1265	
	93.93	94.04	93.70	
Yes	182	98	82	
	5.67	5.41	6.07	
Don't know/not sure	13	10	3	
	0.40	0.55	0.22	
Rode as a passenger in motor vehicle when driver under influence of alcohol	6343			*
No	5901	3030	2767	
	93.03	92.24	93.86	
Yes	442	255	181	
	6.97	7.76	6.14	
Treated in emergency room for any reason related to alcohol use	6461			ns
No	6454	3345	2996	
	99.89	99.85	99.93	
Yes	7	5	2	
	0.11	0.15	0.07	

† *Among respondents indicating consuming at least one drink of any alcoholic beverage in the past 30 days*

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 19C: DPH Patient Survey Alcohol Consumption by Education (Among All 6,934 Respondents)

	Total N %	Education < Bachelor's (N=3282)	≥ Bachelor's (N=3595)	p-value
Number of days respondent consumed an alcoholic beverage in past 30 days	6252			****
0 days	2569 41.09	1555 52.78	1007 30.59	
1-10 days	2609 41.73	1066 36.18	1537 46.69	
11-20 days	656 10.49	187 6.35	469 14.25	
21-30 days	418 6.69	138 4.68	279 8.48	
Money spent on alcohol in past 30 days	5328			****
$0	2727 51.18	1604 62.51	1114 40.51	
$1 to $100	2260 42.42	889 34.65	1369 49.78	
$101 to $200	240 4.50	45 1.75	194 7.05	
$201 or more	101 1.90	28 1.09	73 2.65	
Drove/operated motor vehicle while under the influence of alcohol †	3211			ns
No	3016 93.93	1160 94.16	1851 93.77	
Yes	182 5.67	66 5.36	116 5.88	
Don't know/not sure	13 0.40	6 0.49	7 0.35	
Rode as a passenger in motor vehicle when driver under influence of alcohol	6343			**
No	5901 93.03	2853 94.10	3034 92.02	
Yes	442 6.97	179 5.90	263 7.98	
Treated in emergency room for any reason related to alcohol use	6461			ns
No	6454 99.89	3062 99.87	3377 99.91	
Yes	7 0.11	4 0.13	3 0.09	

† *Among respondents indicating consuming at least one drink of any alcoholic beverage in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Non-Medical Use of Prescription Drugs and Other Substances

All respondents were asked to report on their non-medical use or and behaviors related to prescription drugs and other substances in the past 30 days. Results are summarized in *Tables 20A, 20B, and 20C*, with comparisons by gender, age group, and educational attainment, respectively.

Ninety percent of survey respondents reported no use of cocaine or crack, heroin, anxiety drugs, sleeping drugs, prescription opioids, or other drugs for non-medical purposes in the past 30 days. 3% of respondents reported using anxiety drugs such as sedatives , tranquilizers, and anxiolytics, and 2% reported using sleeping drugs such as benzodiazepines and barbiturates in the past 30 days. Less than 2% reported using prescription opioids such as Oxycodone, OxyContin, Hydrocodone, Vicodin, Morphine, Methadone, or Fentanyl in the past 30 days. Less than 1% reported using cocaine, crack, or heroin in the past 30 days.

Thirty-five percent of respondents who reported any use of cocaine or crack, heroin, anxiety drugs, sleeping drugs, prescription opioids, or other drugs for non-medical purposes in the past 30 days reported non-medical use of prescription drugs between 1 and 10 days out of the past 30, while 65% reported non-medical use of prescription drugs and other substances for more than 10 out of 30 days.

One percent of respondents who reported any use of cocaine or crack, heroin, anxiety drugs, sleeping drugs, prescription opioids, or other drugs for non-medical purposes in the past 30 days being treated in an emergency room or urgent care facility for reasons related to non-medical use of prescription drugs and other substances in the past 30 days. There were no significant differences in the proportion of respondents treated in emergency rooms for non-medical use of prescription drugs or other substances in the past 30 days by gender, age, or education.

Fifty-nine percent of survey respondents reported cutting down or stopping the use of other prescription drugs, over the counter medications, or other substances since beginning marijuana use. A significantly larger proportion of female respondents compared to male (63% vs. 55%).

Sixty percent of survey respondents reported spending $0 on prescription drugs or other substances, and 31% of respondents reported spending between $1 and $100, and 9% reported spending over $100 in the past 30 days. A larger proportion of male respondents than female reported spending $0 on any other prescription drugs (63% vs. 57%), while a larger proportion of female respondents than male reported spending between $1 and $100 on any other prescription drugs (34% vs. 28%) in the past 30 days. A larger proportion of respondents under age 51 than over reported spending $0 on any other prescription drugs (67% vs. 53%), while a larger proportion of older respondents than younger reported spending between $1 and $100 on any other prescription drugs in the past 30 days (36% vs. 25%). A larger proportion of respondents without a Bachelor’s degree than respondents with a degree reported spending $0 on any other prescription drugs in the past 30 days (65% vs. 56%), while a larger percent of respondents with a Bachelor’s degree than without reported spending between $1 and $100 (34% vs. 27%).

Four percent of respondents who indicated using prescription drugs or other substances for non-medical purposes in the past 30 days reported operating a vehicle while under the influence or prescription or other drugs in the past 30 days. 2% of survey respondents reported riding as a passenger in a vehicle while the driver was under the influence or prescription or other drugs in the past 30 days.

Table 20A: DPH Patient Survey Non-Medical Use of Prescription Drugs and Other Substances by Gender (Among All 6,934 Respondents)

	Total N %	Gender		
		Male (N=3732)	**Female** (N=3056)	**p-value**
Used any of the following drugs for non-medical purposes †	6435			
None	5852 90.07	3175 90.92	2585 89.20	*
Cocaine or Crack	16 0.25	9 0.26	7 0.24	ns
Heroin	2 0.03	1 0.03	1 0.03	ns
Antianxiety drugs (sedatives, Tranquilizers, Anxiolytics)	185 2.85	84 2.41	99 3.42	*
Sleeping drugs (Benzodiazepines, Barbiturates)	145 2.23	69 1.98	74 2.55	ns
Prescription opioids (Oxycodone/ OxyContin, Hydrocodone/ Vicodin, Morphine, Methadone, Fentanyl)	123 1.89	66 1.89	53 1.83	ns
Other	112 1.72	53 1.52	56 1.93	ns
Number of days respondent used any of the above drugs in past 30 days	351			ns
1-10 days	124 35.33	56 34.36	66 36.46	
More than 10 days	227 64.67	107 65.64	115 63.54	
Treated in an emergency room for any reason related to use of any of the above drug(s) ‡	462			ns
No	457 98.92	217 98.64	234 99.57	
Yes	5 1.08	3 1.36	1 0.43	

† *Percentages sum to more than 100% because respondents could choose more than one option*
‡ *Among respondents indicating USING cocaine or crack, heroin, antianxiety, sleeping, or prescription opioids for non-medical purposes in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 20A: DPH Patient Survey Non-Medical Use of Prescription Drugs and Other Substances by Gender (Among All 6,934 Respondents)

	Total N %	Gender		
		Male (N=3732)	**Female** (N=3056)	**p-value**
Since beginning to use marijuana, respondent cut down or stopped using any other prescription drugs, over the counter medications, or other substance	6010			****
No	2475	1433	1006	
	41.18	44.67	37.12	
Yes	3535	1775	1704	
	58.82	55.33	62.88	
Total money spent on drugs (prescription or other substances) in past 30 days	4762			****
$0	2870	1598	1228	
	60.27	62.72	57.28	
$1 to $100	1453	704	729	
	30.51	27.63	34.00	
$101 to $200	184	111	70	
	3.86	4.36	3.26	
$201 or more	255	135	117	
	5.35	5.30	5.46	
Drove /operated motor vehicle when under the influence (medical prescription drugs only) †	5746			ns
No	5436	2943	2407	
	94.60	94.63	94.50	
Yes	205	107	98	
	3.57	3.44	3.85	
Don't know/not sure	105	60	42	
	1.83	1.93	1.65	
Rode as a passenger in motor vehicle when under the influence of any of the above drugs	6175			ns
No	6031	3247	2696	
	97.67	97.83	97.47	
Yes	144	72	70	
	2.33	2.17	2.53	

† *Among respondents indicating NOT using cocaine or crack, heroin, antianxiety, sleeping, or prescription opioids for non-medical purposes in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 20B: DPH Patient Survey Non-Medical Use of Prescription Drugs and Other Substances by Age Group (Among All 6,934 Respondents)

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
Used any of the following drugs for non-medical purposes †	6435			
None	5852 90.07	3080 91.31	2678 88.94	**
Cocaine or Crack	16 0.25	15 0.44	1 0.03	***
Heroin	2 0.03	1 0.03	1 0.03	ns
Antianxiety drugs (sedatives, Tranquilizers, Anxiolytics)	185 2.85	89 2.64	93 3.09	
Sleeping drugs (Benzodiazepines, Barbiturates)	145 2.23	61 1.81	81 2.69	*
Prescription opioids (Oxycodone/ OxyContin, Hydrocodone/ Vicodin, Morphine, Methadone, Fentanyl)	123 1.89	43 1.27	76 2.52	***
Other	112 1.72	46 1.36	65 2.16	*
Number of days respondent used any of the above drugs in past 30 days	351			*
1-10 days	124 35.33	62 41.89	60 30.30	
More than 10 days	227 64.67	86 58.11	138 69.70	
Treated in an emergency room for any reason related to use of any of the above drug(s) ‡	462			ns
No	457 98.92	191 97.95	257 99.61	
Yes	5 1.08	4 2.05	1 0.39	

† *Percentages sum to more than 100% because respondents could choose more than one option*
‡ *Among respondents indicating USING cocaine or crack, heroin, antianxiety, sleeping, or prescription opioids for non-medical purposes in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 20B: DPH Patient Survey Non-Medical Use of Prescription Drugs and Other Substances by Age Group (Among All 6,934 Respondents)

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
Since beginning to use marijuana, respondent cut down or stopped using any other prescription drugs, over the counter medications, or other substance	6010			***
No	2475	1195	1224	
	41.18	38.75	43.37	
Yes	3535	1889	1598	
	58.82	61.25	56.63	
Total money spent on drugs (prescription or other substances) in past 30 days	4762			****
$0	2870	1661	1161	
	60.27	66.63	53.04	
$1 to $100	1453	629	798	
	30.51	25.23	36.46	
$101 to $200	184	75	104	
	3.86	3.01	4.75	
$201 or more	255	128	126	
	5.35	5.13	5.76	
Drove /operated motor vehicle when under the influence (medical prescription drugs only) †	5746			***
No	5436	2898	2449	
	94.60	95.77	93.19	
Yes	205	83	120	
	3.57	2.74	4.57	
Don't know/not sure	105	45	59	
	1.83	1.49	2.25	
Rode as a passenger in motor vehicle when under the influence of any of the above drugs	6175			ns
No	6031	3130	2800	
	97.67	97.66	97.77	
Yes	144	75	64	
	2.33	2.34	2.23	

† *Among respondents indicating NOT using cocaine or crack, heroin, antianxiety, sleeping, or prescription opioids for non-medical purposes in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 20C: DPH Patient Survey Non-Medical Use of Prescription Drugs and Other Substances by Education (Among All 6,934 Respondents)

	Total N %	Education		
		< Bachelor's (N=3282)	**≥ Bachelor's** (N=3595)	**p-value**
Used any of the following drugs for non-medical purposes †	6435			
None	5852 90.07	2754 89.53	3083 90.57	ns
Cocaine or Crack	16 0.25	10 0.33	6 0.18	ns
Heroin	2 0.03	2 0.07	0 0.00	ns
Antianxiety drugs (sedatives, Tranquilizers, Anxiolytics)	185 2.85	96 3.12	89 2.61	ns
Sleeping drugs (Benzodiazepines, Barbiturates)	145 2.23	64 2.08	81 2.38	ns
Prescription opioids (Oxycodone/ OxyContin, Hydrocodone/ Vicodin, Morphine, Methadone, Fentanyl)	123 1.89	79 2.57	44 1.29	***
Other	112 1.72	57 1.85	55 1.62	ns
Number of days respondent used any of the above drugs in past 30 days	351			ns
1-10 days	124 35.33	50 30.30	74 39.78	
More than 10 days	227 64.67	115 69.70	112 60.21	
Treated in an emergency room for any reason related to use of any of the above drug(s) ‡	462			ns
No	457 98.92	233 98.31	224 99.56	
Yes	5 1.08	4 1.69	1 0.44	

† *Percentages sum to more than 100% because respondents could choose more than one option*
‡ *Among respondents indicating USING cocaine or crack, heroin, antianxiety, sleeping, or prescription opioids for non-medical purposes in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

(Continued) Table 20C: DPH Patient Survey Non-Medical Use of Prescription Drugs and Other Substances by Education (Among All 6,934 Respondents)

	Total N %	Education		
		< Bachelor's (N=3282)	**≥ Bachelor's** (N=3595)	**p-value**
Since beginning to use marijuana, respondent cut down or stopped using any other prescription drugs, over the counter medications, or other substance	6010			ns
No	2475	1162	1309	
	41.18	41.56	40.92	
Yes	3535	1634	1890	
	58.82	58.44	59.08	
Total money spent on drugs (prescription or other substances) in past 30 days	4762			****
$0	2870	1443	1421	
	60.27	65.24	55.90	
$1 to $100	1453	597	856	
	30.51	26.99	33.67	
$101 to $200	184	78	105	
	3.86	3.53	4.13	
$201 or more	255	94	160	
	5.35	4.25	6.29	
Drove /operated motor vehicle when under the influence (medical prescription drugs only) †	5746			ns
No	5436	2556	2866	
	94.60	94.32	94.87	
Yes	205	100	105	
	3.57	3.69	3.48	
Don't know/not sure	105	54	50	
	1.83	1.99	1.66	
Rode as a passenger in motor vehicle when under the influence of any of the above drugs	6175			**
No	6031	2849	3169	
	97.67	97.00	98.26	
Yes	144	88	56	
	2.33	3.00	1.74	

† *Among respondents indicating NOT using cocaine or crack, heroin, antianxiety, sleeping, or prescription opioids for non-medical purposes in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Combination of Substances

All respondents were asked to report on their combination use of alcohol, marijuana, or other drugs in the past 30 days. Results are summarized in *Tables 21A, 21B, and 21C*, with comparisons by gender, age group, and educational attainment, respectively. Thirty-seven percent of survey respondents reported using a combination of alcohol, marijuana, or other drugs in the past 30 days. A significantly larger proportion of respondents younger than 51 years old compared to older respondents reported combination use between 1 to 10 days out of the past 30 (25% vs. 19%), as did a significantly larger proportion of respondents with a Bachelor’s degree compared to respondents without a degree (27% vs. 16%). A larger proportion of respondents older than 50 years old compared to younger respondents reported combination use for at least 11 days out of the past 30 (19% vs. 11%), as did a larger proportion of respondents with a Bachelor’s degree compared to respondents without a degree (16% vs. 13%).

Nine percent of respondents who indicated using a combination of alcohol, marijuana, or other drugs in the past 30 days reported operating a vehicle while under the influence of combination substances in the past 30 days. There were no significant differences in the proportion of respondents who reported driving/operating a car or other motor vehicle under the influence of any combination of alcohol, marijuana, or other drugs by gender, age, or education.

Table 21A: DPH Patient Survey Combination of Substances by Gender (Among All 6,934 Respondents)

	Total N %	Age Group		
		≤ 50 years (N=3584)	**≥ 51 years** (N=3188)	**p-value**
Number of days respondent used a combination of alcohol, marijuana, or other drugs (prescription drugs or other substances) in past 30 days	5947			****
None	3772	1989	1714	
	63.43	64.12	62.28	
1-10 days	1321	782	521	
	22.21	25.21	18.93	
More than 10 days	854	331	517	
	14.36	10.67	18.79	
Drove/operated a motor vehicle when under the influence of any combination of alcohol, marijuana, or other drugs †	2109			ns
No	1918	975	920	
	90.94	90.28	91.45	
Yes	191	105	86	
	9.06	9.72	8.55	

† *Among respondents indicating use of a combination of alcohol, marijuana, or other drugs in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 21B: DPH Patient Survey Combination of Substances by Age Group (Among All 6,934 Respondents)

	Total N %	Age Group ≤ 50 years (N=3584)	≥ 51 years (N=3188)	p-value
Number of days respondent used a combination of alcohol, marijuana, or other drugs (prescription drugs or other substances) in past 30 days	5947			****
None	3772 63.43	1989 64.12	1714 62.28	
1-10 days	1321 22.21	782 25.21	521 18.93	
More than 10 days	854 14.36	331 10.67	517 18.79	
Drove/operated a motor vehicle when under the influence of any combination of alcohol, marijuana, or other drugs †	2109			ns
No	1918 90.94	975 90.28	920 91.45	
Yes	191 9.06	105 9.72	86 8.55	

† *Among respondents indicating use of a combination of alcohol, marijuana, or other drugs in the past 30 days*

**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Table 21C: DPH Patient Survey Combination of Substances by Education (Among All 6,934 Respondents)

	Total N %	Education		
		< Bachelor's (N=3282)	**≥ Bachelor's** (N=3595)	**p-value**
Number of days respondent used a combination of alcohol, marijuana, or other drugs (prescription drugs or other substances) in past 30 days	5947			****
None	3772	1995	1770	
	63.43	71.00	56.64	
1-10 days	1321	463	854	
	22.21	16.48	27.33	
More than 10 days	854	352	501	
	14.36	12.53	16.03	
<u>Drove/operated</u> a motor vehicle when under the influence of any combination of alcohol, marijuana, or other drugs †	2109			ns
No	1918	724	1189	
	90.94	91.88	90.35	
Yes	191	64	127	
	9.06	8.12	9.65	

† *Among respondents indicating use of a combination of alcohol, marijuana, or other drugs in the past 30 days*
**p<0.05; **p<0.01; ***p<0.001; ****p<0.0001; ns=not significant*

Discussion

There were no notable differences between respondent distributions of gender, age, or county of residence groups comparing all respondents of the 2018 Medical Use of Marijuana Patient Survey to the full eligible population, suggesting that, although the response rates was low at 16%, the sample of 6934 respondents in this study was representative of the Massachusetts Medical Use of Marijuana patient population. In this survey respondents were asked to type in their Medical Marijuana Registration number and that may have led to concerns about confidentiality.

Respondents indicated using marijuana for an average of 23.5 days out of the past 30, with over 60% reporting marijuana use at least 21 out of the past 30. Over 90% of respondents indicated some certified medical use of marijuana, 6% some uncertified medical use, and 17% indicated some recreational use. These categories are not mutually exclusive, suggesting that while most respondents are using marijuana to treat medical conditions, but some are also using recreationally.

Results from this survey suggest that respondents appear to be treating a wide range of medical conditions, and often more than one at a time. The top 5 medical conditions being treated were anxiety (60% or all respondents), chronic pain (46%), insomnia (43%), depression (42%), and stress (41%), and the average number of conditions being treated by medical marijuana is 4.7.

Patients registered with the Massachusetts Department of Public Health Medical Use of Marijuana Program were certified by a qualified physician or clinician because of a debilitating medical situation, which often has multiple associated medical conditions for which marijuana use can assuage. Results from this study confirm this, suggesting that patients believe marijuana use is alleviating multiple.

While a qualified physician or clinician may certify a patient with a debilitating medical condition for medical use of marijuana, they are not required to write a prescription specifying the product type the patient must use (although they may make recommendations as the patients is under their care). As such, patients have access to a wide range of marijuana administration methods. Results from this study indicate that respondents use multiple methods of administration, over the course of 30 days, with an average of 2.9 methods. In fact, less than one fifth of all respondents reported only one method of marijuana administration, while over 30% reported using 4 or more. The most common method of marijuana administration was smoking dried flower (65%), followed by vaporized marijuana concentrate (62%) and edible marijuana products (51%).

All respondents were asked questions related to perceptions of the Medical Use of Marijuana Program. In general, respondents reported favorably towards medical use of marijuana. Almost all respondents considered the use to be effective in treating their conditions with over 65% of respondents reported that they believed use of marijuana or marijuana products has been “very effective” and an additional 26% believed use of marijuana to be “effective”. Also almost 90% of respondents reported that they had “somewhat high” or “very high” confidence that they were receiving safe, uncontaminated products when purchasing marijuana or marijuana products at a licensed dispensary. 94% reported feeling “somewhat safe” or “very safe” when purchasing medical marijuana at a licensed dispensary, and 66% reported “somewhat high” or “very high” knowledge of their recommended marijuana or marijuana product based on the information provided by their certified practitioner. Findings from this study also suggest that respondents perceive marijuana use to have very high rates of positive outcomes and little obvious harm. 78% of respondents reported positive changes in their mood or mental health, 67% reported improved physical health, and 83% reported no negative outcomes or consequences related to their marijuana use. Thus, respondents are highly satisfied with their access to marijuana products and information and believe they have largely benefitted from medical use of marijuana with very little, if any negative effects.

Finally, almost 60% or respondents who reported use of prescription drugs, over-the-counter, medications, or other substances (for medical use only) also reported cutting down or stopping use of other prescription drugs, over the counter medications, or other substances since beginning to use marijuana.

Conclusion/Public Health Implications

The Massachusetts Medical Marijuana Program is considered to be a very important and valuable asset to the mental and physical health of participants. Respondents of the 2018 Medical Use of Marijuana Patient Survey indicate general satisfaction with the program, few negative outcomes, and in particular have reported a reduction in the use of other drugs and medications as a result of marijuana use.

Task 2: Incidents of Impairment and Hospitalization

Chapter 1: Measuring Marijuana Exposure and its Effects Related to Driving Impairment: A State of the Science Review

Introduction

In states that have chosen to legalize marijuana, one concern among public health and public safety professionals and citizens is the potential impact of marijuana legalization on motor vehicle crashes (MVCs). Studies suggest that recent cannabis use is associated with an increased crash risk between 22%-100% (Asbridge, Hayden, & Cartwright, 2012; G. Li, Chihuri, & Brady, 2017; Rogeberg & Elvik, 2016). However, there are challenges to the detection and deterrence of marijuana-impaired driving. Although a substantial body of literature related to methods for identifying acute marijuana exposure and impairment exists, best practice for doing so has yet to be established. As such, states that are implementing legalization of marijuana are doing so without established guidelines for detecting marijuana-impaired driving in a manner that is relatively non-invasive and sufficiently accurate to prove impairment. Washington State has selected 5ng/mL as a per se limit; Colorado uses this level as "presumptive evidence" of impairment. This report reviews the relevant scientific literature on the topic of measuring marijuana as it relates to driving impairment.

Scientific Foundation

The content of this report is predicated on several accepted premises that are derived from current scientific knowledge. First, with regard to marijuana pharmacokinetics, it is established that combustion (burning) of the dried flower of the cannabis plant converts tetrahydrocannabinolic acid to Δ^9-tetrahydrocannabinol (THC) (Huestis, 2007). THC is then metabolized in the liver to psychoactive 11-OH-Δ9-tetrahydrocannabinol (OH-THC; pronounced "hydroxy THC") and non-psychoative 11-nor-9-carboxy-Δ9-tetrahydrocannabinol (THC-COOH, pronounced "carboxy THC") which is excreted in urine (Grotenhermen, 2003; Huestis, 2007).

The Δ^9-THC is the main source of the pharmacological effects caused by cannabis consumption. Cannabinoids exert many effects through activation of G-protein-coupled cannabinoid receptors in the brain and peripheral tissues (Grotenhermen, 2003). There is also evidence for non-receptor-dependent mechanisms (Grotenhermen, 2003). Cannabis is usually inhaled or taken orally. The pharmacokinetics of THC vary by route of administration (Grotenhermen, 2003; Huestis, 2007; Newmeyer et al., 2017a). After inhalation, plasma THC concentration peak within a few minutes (Grotenhermen, 2003). Psychotropic effects begin within seconds to a few minutes, reach a maximum after 15-30 minutes, and taper off within 2-3 hours (Grotenhermen, 2003). Following oral ingestion, psychotropic effects onset after 30-90 minutes, reach a maximum after 2-3 hours, and last for about 4-12 hours, depending on dose and specific effect (Grotenhermen, 2003; Hollister et al., 1981; Wall, Sadler, Brine, Taylor, & Perez-Reyes, 1983).

With regard to biological measurement of marijuana exposure, we take blood to be the "gold standard" in terms of the matrix that has been best studied. Urine and oral fluid have also been studied to a great extent. The relationship between route of administration and measurement of cannabis in oral fluid is an area of ongoing research and will be described below.

Prevalence of Cannabis-Positive Drivers in Motor Vehicle Crashes

In the U.S. estimates of the prevalence of marijuana involvement in MVCs vary. As part of the background information for this state of the science review (SSR) we systematically collected all studies reporting prevalence of cannabis involvement in MVCs in the U.S. At the national level, one study found that the prevalence of cannabis-involved motor vehicle crashes in 1982 was 10% and that by 2001, the prevalence had increased to 19.6% (Macdonald et al., 2003). Conversely, another nationwide study found that the overall prevalence of cannabis in motor vehicle crashes between the years 1993-2014 remained constant at 10.4% which suggests that prevalence had not increased significantly since 1982 (G. Li et al., 2017).

Studies have also been conducted at the state level in locations that have made substantial changes to their marijuana policy by allowing the legal sale of marijuana for medical and/or recreational purposes. States that have undergone such policy changes provide insight that may be especially relevant for Massachusetts. In Colorado, one study conducted between the years 1994-2011 found that there was an increase in prevalence of cannabis related motor vehicle crashes from 4.5% in 1994 to 10% in 2011, after medical marijuana was commercialized in mid-2009 (Salomonsen-Sautel, Min, Sakai, Thurstone, & Hopfer, 2014). Findings from another study in Colorado show that in 2006 the prevalence of cannabis related motor vehicle crashes in Colorado was 6.9% and increased to 19% by 2014; Colorado's citizens voted in 2012 to legalize marijuana for non-medical use (Rocky Mountain High Intensity Drug Trafficking Area, 2015).

Results from studies in Washington State indicate that about 10% of drivers in fatal crashes between 2010-2014 had delta-9-THC in their blood. The prevalence such crashes was stable prior to legalization of recreational marijuana use, but approximately 9 months after legalization took effect it began increasing by nearly 10 percentage points per year (Tefft, Arnold, & Grabowski, 2016). Another study from 2013-2014 showed the prevalence of cannabis related motor vehicle crashes in Washington State to be between 7-8% (Banta-Green, Rowhani-Rahbar, Ebel, Andris, & Qiu, 2016). Overall, there is conflicting evidence, but studies reviewed here indicate that the prevalence of cannabis-positive drivers in motor vehicle crashes has increased in states where marijuana policy has become more permissive. It is important to note that in these prevalence studies, whether drivers were actually impaired by cannabis at the time of the crash was not determined. Collecting a blood test from surviving drivers presents a challenge due to the invasive nature of blood collection; time delays between a crash and blood testing are common and problematic since delta-9-THC levels rapidly decrease after smoking (Wood, Brooks-Russell, & Drum, 2016).

Study Purpose

The establishment of fair and appropriate methods to detect marijuana-related driving impairment could help ensure public safety in environments with legal marijuana and provide important information about prevalence. This review of the literature is undertaken for the purpose of summarizing the available scientific evidence. Specifically, we sought to: 1) Describe the analytical methods used to quantify marijuana exposure in laboratory and field settings; 2) Describe measurements of marijuana-related impairment that are relevant to operating a motor vehicle; and 3) Provide an integration and discussion of evidence for approaches that link marijuana-related measurements of exposure with measurements of impairment that are relevant to operating a motor vehicle.

Research Questions

RQ1: What is the most current science on quantifying marijuana exposure in an analytical chemistry laboratory or clinical laboratory setting in different matrices (blood, oral fluid, urine) through quantitative measurement of marijuana and its metabolites?

RQ2: What methods (e.g., devices, tests, kits, etc.) are currently available for quantifying marijuana exposure in the field and what is the precision and accuracy of these methods for detecting marijuana exposure (compared to laboratory-based methods)?

RQ3a: What are the cognitive and behavioral indicators of marijuana exposure that are relevant to operating a motor vehicle? How have these been characterized at baseline (non-impaired) levels?

RQ3b: How are the cognitive and behavioral effects of marijuana impairment measured in laboratory settings and in field settings? What validation has been conducted? What is the level of accuracy for determining impairment/non-impairment?

Methods

We approached the research questions above through a systematic literature search process. In instances when a high-quality review article was already published on the topic of interest, we used the review as a starting point and extracted information from the studies gathered by the review authors. We then conducted a search that covered the time period between the publication of the latest paper included in the review and December 2017. We conducted the searches in the following order: RQ2, RQ3a, RQ3b, RQ1. More information is provided below, and details of the search terms are provided in

Table 1. Search Strings.

Research Question 1: Quantifying Marijuana Exposure in a Laboratory Setting

Our systematic search conducted for R2 identified studies that were relevant to research question 1. Specifically, all identified R2 studies utilized similar confirmatory laboratory testing methods to identify marijuana exposure in blood, urine, and or saliva.

Given the consistency in the studies identified in R2, we were confident in our assessment that said methods were the state of the science. As such, the goal of our research specific to R1 was to identify one or more studies that confirmed our assessment. We did not deem a systematic review of the literature necessary to accomplish this goal. Instead, we developed several search strings to identify studies that provided an overview of current methods as well as potential future directions for laboratory marijuana exposure quantification, particularly in regards to new quantification and interpretation methods for THC metabolites.

We tested both complex and simple search strings to accomplish this goal. All search strings were tested on PubMed. We found that one particular simple search string performed best. The string identified 22 total references. Titles and abstracts were reviewed for relevance and a recent article written by a leading expert in the field was identified. Given that the content of this article matched closely to what we were attempting to procure, we chose to utilize it as the center piece of our response to this question. Other identified references, either from the broad R1 search or the systematic, targeted R2 search were utilized as appropriate.

Research Question 2: Methods for Quantifying Marijuana Exposure in a Field Setting

We conducted a systematic search of the current literature related to on-site testing devices, sometimes called point-of-collection tests (POCT), for measuring marijuana. We did not restrict the search to specific biological matrices (i.e. only blood, only oral fluid). We conducted our search in both PubMed and Web of Science, and searched the relevant gray literature (e.g. AAA Foundation, National Highway Transportation Safety Administration, etc.) for relevant studies. The search was limited to studies published in or after 1995.

Search strings were developed in consultation with a University of Massachusetts Amherst librarian with expertise in health science search string development. Searches were conducted on each separate database and abstracts were screened for appropriateness. To be considered for full text review, abstracts had to convey that the study met the following criteria: (1) was published in English, (2) was conducted in humans, (3) examined field devices or kits, and (4) examined marijuana exposure.

Studies identified as candidates for inclusion after the abstract screening process subsequently had their full text reviewed for appropriateness. After full text review, studies were excluded if: (1) Device assessed was only for collection and storage of sample; (2) Study did not assess devices capability as a rapid on-site test; (3) Study assessed devices used to measure synthetic cannabinoids; (4) Device assessed was a laboratory device (5) Study did not assess any on-site device; (6) Study did not provide sensitivity or specificity measurements of THC for tested device, or (7) Text of study was not in English.

Of 154 combined peer reviewed results identified through our initial searches, 84 were selected for full text review. A majority (61%) of these studies were obtained through PubMed. We identified one study from the gray literature for full text review.

During full text review, we identified a systematic review and meta-analysis conducted on our topic of interest in 2017 (latest year of included studies was 2015). We used this study as the centerpiece of our review and subsequently reviewed identified studies from 2015-2017 to update and supplement this already completed review. We identified 6 studies that were published beyond the 2015 review. Thus, these 7 studies form the basis of our review for this question. We reviewed the reference list of the 6 more recent, original studies and cross-checked this with the review article to ensure that all important papers relevant to the topic were included either in the existing review article or in the original research studies we identified and included.

We extracted information about sensitivity and specificity of the POCT devices as compared to laboratory methods, and we report accuracy when possible. Sensitivity refers to the percentage of cannabis-using individuals that were correctly identified as positive for cannabis. Specificity refers to the percentage of individuals who did not use cannabis that were correctly identified as non-users by a negative test result.

Given the complexity of the studies in this area, we summarized the results in several tables. In synthesizing and interpreting the studies, as a whole, we weighted studies with a larger sample size, controlled laboratory conditions, and comparisons between multiple devices as more salient than others.

Research Question 3A: Cognitive and Behavioral Effects Relevant to Driving

A systematic search of the current literature related to cognitive and behavioral indicators of marijuana exposure was conducted. Following advice from a health sciences librarian, we conducted our searches in both PubMed and Web of Science. We also sought input from the librarian for developing and refining our search string. Searches were conducted on each separate database and abstracts were screened for appropriateness. We did not limit the date range on this search.
Early in the review process, we identified a recent systematic review (Bondallaz et al., 2016) whose content matched closely with what we were attempting to procure. We judged this review to be of high quality, and therefore used it as the basis for our response to RQ3a. We extracted all individual studies from the review and reviewed them independently. We subsequently conducted an update search, using a search string developed in consultation with a health sciences librarian to identify any studies on the subject of interest published after 2013 (the newest study reviewed in the review article).

In total, 24 studies were extracted from the Bondallaz review. Our update search (2013-2017) initially yielded 367 results from PubMed and 316 from Web of Science. After abstract screening and removal of duplicates, we identified 15 studies for full text review from PubMed and 2 studies for full text review from Web of Science. After full text review, we identified an additional 5 studies that had been published on the topic since the Bondallaz review for a total of 29 studies included in our review.

Detailed information such as THC dosage, user population, sample size, study setting, indicator tested, measurement approach, and results were extracted from studies included in final review. In order to standardize the information extraction, we defined the relevance of cognitive / behavioral indicators measured according to the recommended behavioral measurements outlined in Guidelines for Research on Drugged Driving (J Michael Walsh, Verstraete, Huestis, & Mørland, 2008). These include automotive behavior, control behavior, and executive planning. The only additional category defined outside of the three listed above was, “driving safety/performance metric.” This was only defined for driving simulator and on road studies which measured direct driving metrics such as mean speed and SD lateral position. This approach was adapted from the Bondallaz review which identified said behavioral measurements and grouped typical neurocognitive tests (Tower of London Task, Critical Tracking Task etc.) according to their corresponding behavioral measurement (Bondallaz et al. 2016 – Table 1) (Bondallaz et al., 2016). We expanded on this by incorporating these behavioral measurement categories into our analytic table.

After information from all studies was extracted to the large summary table, we further refined the analysis in order to enhance the digestibility of the results. We created four separate analytic tables grouped by study setting (lab, simulator, on road, and observational). Each table presents a refined analysis, where detailed results are omitted in favor of a simple summary of the results with regard to the impact of marijuana on task performance. We documented whether marijuana exposure hurt performance, improved performance, or had no effect on performance on specified tests. These tables are designed to allow the reader to digest the results at a higher level and examine trends otherwise invisible at increased levels of granularity.

Research Question 3B: Field Measurement of Marijuana’s Effects and Accuracy for Determining Impairment

The first component of research question 3b, which addresses how cognitive and behavioral effects of marijuana exposure are measured in a laboratory setting, was answered using the search results from research question 3a. Please refer to RQ3a methods for details on the search methods. Search efforts for this research question focused only on the latter part of the question, which attempts to determine how the cognitive behavioral impacts of marijuana exposure are measured in field settings and the validation and accuracy of those tools.

To accomplish this, four separate search strings / strategies were developed to answer this question (Table 1. Search Strings). PubMed was searched. The first string scanned the peer reviewed literature for studies of screening tools that measure cognitive/behavioral indicators of marijuana exposure. After abstract screening, this search did not return any results.

The second string searched the peer reviewed literature for studies of screening tools that measured indicators of cognitive / behavioral deficits. This was done to gain a broader understanding of currently available validated tools. The overall goal was to identify tools that may have utility when applied to measuring marijuana exposure. After abstract screening, this search returned 2 results.

The third string searched the peer reviewed literature for studies that assessed the validity of standardized field sobriety tests (SFSTs) for measuring marijuana. This search was conducted due to the fact that SFSTs are currently used by law enforcement to determine impairment. After abstract screening, this search returned 3 results.

The fourth component of this approach was to scan of the grey literature / internet for tools and or screening devices that might have utility in measuring cognitive or behavioral impacts of marijuana exposure. These included mobile applications. This search returned 5 results, but we excluded 2 apps that were designed generally for cognitive impairment but did not touch directly on tasks used to measure marijuana-related effects in laboratory settings. Results from the four searches were extracted into two separate analytic tables, one for peer reviewed results, and the other for non-peer reviewed results.

Table 1. Search Strings

Research Question	Database	Search String / Search Terms
RQ1	PubMed	Marijuana AND Biological Matrices
RQ2	PubMed	((((marijuana OR cannabis OR Cannabinoids OR Tetrahydrocannabinol OR THC) AND (On-site OR rapid OR field) AND (method OR test OR evaluation OR screening OR measurement OR "Point-of-Care Testing" AND (Device OR kit)))))
RQ2	Web of Science	((((marijuana OR cannabis OR Cannabinoids OR Tetrahydrocannabinol OR THC) AND (On-site OR rapid) AND (test OR evaluation OR "screening" OR "measurement" OR "Point-of-Care Testing") AND (Device OR Kit))))
RQ2	NHTSA	Marijuana, Cannabis, Tetrahydrocannabinol. Cannabinoids, On site, Rapid, Test, Evaluation, Measurement, Device
RQ2	AAA Foundation	Marijuana, Cannabis, Tetrahydrocannabinol. Cannabinoids, On site, Rapid, Test, Evaluation, Measurement, Device
RQ3A	PubMed (Initial Search)	(cognitive OR cognition OR behavior) AND motor vehicle AND (operation OR driving OR drive)
RQ3A	Web of Science Initial Search	(cognitive OR cognition OR behavior) AND motor vehicle AND (operation OR driving OR drive)

RQ3A	PubMed (Update Search)	(((neurocognitive OR neurocognition OR cognitive OR cognition OR Behavior OR Behavioral OR Performance))) AND (((driving OR drive))) AND ((marijuana OR cannabis OR Cannabinoids OR Tetrahydrocannabinol OR THC))
RQ3A	Web of Science (Update Search)	(((neurocognitive OR neurocognition OR cognitive OR cognition OR Behavior OR Behavioral OR Performance))) AND (((driving OR drive))) AND ((marijuana OR cannabis OR Cannabinoids OR Tetrahydrocannabinol OR THC))
R3B	PubMed (Search String A)	(Cognitive OR Behavioral) AND (Marijuana OR Cannabis) AND (Field or On-site or road side) AND (Screening OR Test OR app OR measurement OR evaluation)
R3B	PubMed (Search String B)	(mobile) AND (Cognitive OR Behavioral) AND (Dysfunction OR Impairment) AND (app OR Test OR screening OR application OR evaluation OR measurement)
R3B	PubMed (Search String C)	(Marijuana OR Cannabis) AND (Impairment OR Effect OR Influence) AND (Standard Field Sobriety Test or SFST) AND (Accuracy OR Validity OR Effectiveness)
RQ3B	Google (Search D)	Mobile, app, test, screening, (name of specific test) Example: “mobile Stroop test”

Results

Research Question 1: Quantifying Marijuana Exposure in a Laboratory Setting

There are currently three widely accepted laboratory methods for measuring cannabinoids in human biological matrices: immunoassays, chromatography, and mass spectrometry (Huestis & Smith, 2018). Historically, Gas Chromatography with Mass Spectrometry (GC-MS) has been most frequently utilized method. However, recent desire to identify increasingly informative markers of marijuana exposure has led to more frequent utilization of liquid chromatography tandem mass spectrometry (LC-MS/MS) and high-resolution mass spectrometry (HR-MS) measurement methods. Among other advantages, the LC-MS/MS method allows simultaneous quantification of free and conjugated analytes in a single assay (Huestis & Smith, 2018). These methods also offer high sensitivity and specificity for detecting markers of cannabis use (Huestis & Smith, 2018).

LC-MS/MS and HR-MS methods are intriguing because they offer the ability to identify the Phase II THC metabolite (THC-Glucuronide) as well as cannabigerol (CBG), cannabinol (CBN), and tetrahydrocannabivarin (THCV) (Huestis & Smith, 2018). As research on marijuana metabolism continues to advance, particularly as it relates to quantifying exposure, identification of these metabolites becomes increasingly valuable. For instance, quantification of these metabolites can offer information that helps ascertain recent cannabis intake and or the transfer of cannabinoids to alternative matrices such as hair (Huestis & Smith, 2018).

The wide acceptance of these methods is apparent in examining confirmatory laboratory methods utilized in R2 studies. In 100% of the studies we identified in our systematic search of the literature for R2, at least one variation of these methods was used as the gold standard laboratory comparator for performance assessment of point of care detection devices. One recent systematic review related to POCT device assessment restricted their search to include only studies where some type of chromatographic assay was used as the confirmatory method (Scherer et al., 2017). Moreover, among the four most recently published independent studies assessing POCT devices against laboratory methods, 50% utilized the LC-MS/MS method (Edwards, Smith, & Savage, 2017; S. Gentili, Solimini, Tittarelli, Mannocchi, & Busardo, 2016; Newmeyer et al., 2017a; Swortwood et al., 2017). Coupled with the recent analysis from leading experts in quantitative cannabinoid measurement (Huestis & Smith, 2018) these results confirm that measurement of cannabinoids in human biological matrices (blood, oral fluid, and urine) using immunoassays, chromatography, and or mass spectrometry, particularly LC-MS/MS, is the current state of the science.

Research Question 2: Methods for Quantifying Marijuana Exposure in a Field Setting

Point-of-collection testing (POCT) devices make it possible to rapidly screen for cannabis exposure without the use of standard laboratory equipment. These devices typically test oral fluid or urine as these matrices are easier to obtain in a field setting than blood. Compared with urine analysis, oral fluid (OF) collection presents fewer concerns about privacy and adulterations. Drug testing in OF samples usually detects parent drugs, whereas testing of urine samples usually detects metabolites. This makes OF more reflective of recent drug use (Allen, 2011; Bosker & Huestis, 2009; Drummer, 2010; Scherer et al., 2017).

Our systematic search revealed one systematic review plus meta-analysis of 31 studies that was published in mid-2017 (Scherer et al, 2017). The papers that met inclusion criteria for this study were papers evaluating one or more POCT devices and using a validated chromatographic assay as the confirmatory method. Devices had to assess oral fluid as the biological matrix. Studies had to include analysis of cannabinoids as well as cocaine, amphetamines, benzodiazepines (BZD), and opioids. We extracted the results for cannabinoids alone from that publication for inclusion in this report. After exclusions, we also reviewed 6 original studies that were not already covered in the review article.

In the studies we included in this review, we found evidence for 16 POCT devices (i.e. tests, kits, etc.) that evaluate cannabis exposure in a field setting, with varying levels of evidence and validity testing. In their 2017 review, Scherer et al. noted that the most commonly evaluated devices were the Alere™ DDS2 (DDS2), the Dräger DrugTest 5000™ (DT5000), and the Drugwipe™ manufactured by Securetec.(Scherer et al., 2017) Across the studies we reviewed, the Alere™ DDS2 and the Dräger DrugTest 5000™ have the most research evidence available of the POCT devices described in the literature in terms of the number of studies, the number of participants in those studies, and the relevant variables included (i.e. frequent vs. chronic cannabis users, route of cannabis exposure). These devices also performed well according to the Scherer review and thus are the focus of our description.

Our systematic search also returned one study comparing two urine tests (the EZCup and the Multi4Card) which we briefly describe below, though there was less evidence for these approaches to point-of-collection OF testing. We concur with the authors of prior studies who note that the ease of use of OF tests makes them a better candidate for field applications (M. A. Huestis et al., 2013).

Oral Fluid POCT Devices

In the Scherer review, the authors included studies that evaluated the following devices: Rapiscan™, OralLab™, SalivaScreen™, Toxiquik™, Oratect™, Uplink™, Drugwipe™, Dräger DrugTest 5000™, OraLine™, OralSTAT™, Impact™, Uplink™, RapidStat™, BIOSENS Dynamic™, DDS 806™, OrAlert™, and DDS™. The Drugwipe™ (Securetec, Germany) was the most commonly evaluated device among the studies (n = 17), followed by the DrugTest 5000™ (Dräger Safety AG & Co., Germany; n = 12), the Rapiscan™ (Cozart Biosciences Ltd., UK; n = 8) and the Rapid Stat™ (Mavand Solutions, Germany; n = 7) (Scherer et al., 2017). All other devices were evaluated in five or fewer studies. Most other articles we reviewed focused predominantly on the DT5000 or the Alere™ DDS2 (DDS2).

The Alere™ DDS2 is a battery operated handheld device that provides a rapid qualitative assessment (positive/negative) of the presence or absence of delta-9-THC in oral fluid above a concentration of 25ng/mL. Samples are collected using a swab cartridge. After collection, the cartridge is inserted into the device for analysis. Results are available in five minutes and the device does not require oversight while the analysis is taking place. The device features a simple user interface, is lightweight, and has the ability to store up to 10,000 unique samples in its memory at once ("Alere DDS®2 Mobile Test System: Rapid Screening for Drugs of Abuse in Oral Fluid," 2018).

The Dräger DrugTest 5000™ (DT5000) is a portable device that provides a rapid qualitative assessment (positive/negative) of the presence or absence of delta-9-THC above a concentration of 5ng/mL. Samples are collected using a test cassette. After collection, the cassette is inserted into the device for analysis. Results are available in less than 9 minutes in most cases and the device does not require oversight while the analysis is taking place. The device features a simple graphical display that communicates results in plain text and has the ability to store up to 500 results at one time. Stored results are tagged with date and time. Results can also be printed using the Dräger Mobile Printer ("Dräger DrugTest® 5000: Analysis system for detecting drugs," 2018).

Study Designs for Evaluating POCT Devices

A variety of study designs were included in the articles we reviewed. The review article by Scherer et al. included studies of oral fluid POCT drug tests among varied populations (e.g. drivers, drug users, laboratory participants, etc.). Generally speaking, the methodology of the reviewed studies was a slight variation of the following: Participants ingested cannabis either by smoking, vaporizing, or consumption of foods such as brownies in a controlled environment. Upon cannabis consumption, oral fluid specimens were qualitatively analyzed (i.e. pass or fail) using the specified on-site device. Quantitative analytic specimens were concurrently collected to be used as comparators. Analytic samples were either blood or oral fluid (If oral fluid, usually collected with a Quantisal device) ("Quantisal™ Oral Fluid Collection Device," 2018) and were analyzed at a later date using standard, validated laboratory techniques. Results were obtained by comparing the performance of the on-site OF device to the validated laboratory method to determine sensitivity and specificity of the POC device. Most studies defined cut-off values for a “true positive” using only delta-9-THC, although one did conduct additional analyses that included combinations of delta-9-THC and other cannabinoids (we did not report on these results in our analysis). Of note, two studies did not administer cannabis in a controlled setting but rather screened for it in field settings (Edwards et al., 2017; S. Gentili et al., 2016). Otherwise, the general outline of their analyses were the same.

The choice of a confirmation cut-point matters for the correct identification of cannabis exposure via a POCT device. The European Union’s Driving Under the Influence of Drugs, Alcohol, and Medicines (DRUID) program has suggested an 80% target for analytical sensitivity, specificity, and efficiency when evaluating devices (Blencowe, Pehrsson, & Lillsunde, 2010). The DRUID project utilized a confirmatory cutoff of 1ng/mL of delta-9-THC (Verstraete et al., 2011). The U.S. Substance Abuse and Mental Health Services Administration (SAMHSA) has recommended a cutoff of 2ng/mL as a definition for a positive cannabis test in a workplace setting (Department of Health and Human Services, 2015). Thus, the papers we reviewed most commonly report sensitivity and specificity at a variety of cutoffs: 25 ng/mL (the devices own cutoff for the DDS2), 5 ng/mL (the device cutoff for the DT5000), 2 ng/mL (SAMHSA), 1 ng/mL (DRUID), and 0.2 or 0.5 ng/mL (the limit of quantitation). Walsh’s guidelines for research on drugged driving suggest that for drugs with therapeutic use, the confirmatory testing cut-off concentrations should be at least as low as the low end of the therapeutic range. For recreational drugs without any therapeutic use, the guidelines suggest use of a low analytical cut-off (J. M. Walsh, 2008; J Michael Walsh et al., 2008). For cannabis, which is used both medically and recreationally in Massachusetts, and has wide interpersonal variation in pharmacokinetics, establishing a cutoff presents a challenge. We, therefore, present sensitivity and specificity estimates at multiple cut-offs when possible.

Testing revealed, not unexpectedly, that sensitivity and specificity were highest when the cut-off level was highest (25ng/mL in the studies of OF POCT devices). The tests perform better at correctly identifying the presence of THC when higher levels of THC are present in the matrix. The 25ng/mL cutoff was assessed only for the DDS2 device, since this is the level above which it is designed to report a positive test.

Another important factor in examining the performance of POCTs is the cannabis use history of the study participants. Prior studies have documented that POCT device sensitivity is higher in chronic frequent as compared to occasional cannabis smokers due to longer detection windows and higher true positive rates.(M. A. Huestis et al., 2013) Because THC is fat soluble, it is stored in adipose tissue and can leak back into circulation over time, even long after the psychoactive effects of acute cannabis use have ceased (Gunasekaran et al., 2009; Wong et al., 2014; Wong et al., 2013). However, at least one study has concluded that the cannabinoid concentration changes that result from THC reentering circulation are not likely to negatively impact the ability to correctly interpret a drug test (Westin, Mjønes, Burchardt, Fuskevåg, & Slørdal, 2014). In addition, since cannabis is consumed via different routes of exposure (e.g. smoked, vaporized, edible), POCT devices may not assess all possible routes of exposure.

Overall POC Test Performance

Table 2 shows the results from studies of OF POCT devices included in this review, number of participants), route of administration, and the sensitivity, specificity, and accuracy of the device for detecting marijuana exposure as compared to laboratory-based confirmation methods. In this table, we include the overall results from studies that included both chronic and frequent users, as well as results from the meta-analysis and studies conducted in naturalistic settings (e.g. pubs, bars; individuals arrested for driving impairment).

Scherer and colleagues pooled data from the studies in their meta-analysis to examine performance of individual POCT devices for cannabinoid detection. They found that the DDS2 had a sensitivity of 92.5% and specificity of 92.1%. The DT5000 had a sensitivity of 86.5% and specificity of 95.2%. Two other devices, the DrugWipe5+ and RapidStat also performed well for cannabis detection. The RapidStat was not reviewed in any other studies since Scherer's publication. The DrugWipe5A was examined in one naturalistic setting (social venues) and had low sensitivity (29%) and acceptable specificity (88%) (Stefano Gentili, Solimini, Tittarelli, Mannocchi, & Busardò, 2016). We do not discuss it further in this review.

Among all cannabis users, including frequent and occasional users, and across exposure routes, using a confirmation cut-off of 5ng/mL, the DDS2 had a sensitivity of 84.4% and specificity of 94.5% (Swortwood et al., 2017). The DT5000 had a sensitivity of 80.0% and specificity of 91.9% at the same cut-off (Swortwood et al., 2017). The DDS2 was also tested among individuals arrested for operating a motor vehicle while intoxicated (OWI) and compared to blood test values. Using a cutoff of 25 ng/mL that mirrors the devices own cutoff level, Edwards and colleagues report a sensitivity of 88.4 and specificity of 86.9 (Edwards et al., 2017).

Huestis and colleagues (2013) tested the DT5000 among 24 cannabis users (10 occasional, 14 frequent) and provided information about sensitivity 6-8 hours post-inhalation of smoked cannabis because this time frame is relevant for detecting drivers who may be under the influence of recently used marijuana (Huestis et al., 2013) They found the device sensitivity within 6 and 8 hour time frames was 85.6 and 84.7%, respectively, at the confirmation cutoff of 2ng/mL (SAMHSA). Sensitivity within 6 and 8 hour time frames was 84.0 and 82.5%, respectively, at the cutoff of 1ng/mL (DRUID) (Huestis et al., 2013). This can be interpreted to mean that the DT5000 provides a positive test result that accurately identifies approximately 85% of cannabis users who are 6-8 hour post smoking, with 15% false negatives (i.e. the test provides a negative results but the individual has THC levels above the confirmation cutoff).

The DRUID project recommended a threshold of 80% sensitivity, 80% specificity, and 80% accuracy has been established as minimum acceptable level of testing performance for a roadside drug screening test. Across all studies, the DT5000 had a sensitivity range from 80.0%-85.5% and specificity range from 82.5%-95.2%. The DDS2 had a sensitivity range from 84.4%-92.5% and specificity range from 86.9-94.5%.

Table 2. Sensitivity and Specificity of Point of Collection Devices for Measuring Cannabis Exposure in Oral Fluid, All Users

Device(s)	Study	Year	N	Age	Population	Exposure route	Comparison Matrix/Method	Cut off value(s)	Sensitivity	Specificity	Accuracy
17 devices including: DDS™ DT5000 Drugwipe™	Scherer et al.	2017	NA (Meta analysis)	NA	Drivers; Drug users; Laboratory participants	Various	Validated chromato-graphic assay	Not reported	80.5% (7 - 100%)	81.3% (9 - 100%)	41 - 100%
DDS2	Swortwood et al.	2017	545	18-50	Healthy users*	Multiple**	OF (LCMS/MS)	≥ 25 ng/mL ≥ 5 ng/mL ≥ 2 ng/mL ≥ 1n g/L ≥ 0.2 ng/mL	≥ 25 ng/mL =98.5 ≥ 5 ng/mL =84.4 ≥ 2 ng/mL =65.1 ≥ 1 ng/mL =53.2 ≥ 0.2 ng/mL =36.5	≥ 25 ng/mL =84.0 ≥ 5 ng/mL =94.5 ≥ 2 ng/mL =97.6 ≥ 1 ng/mL =98.2 ≥ 0.2 ng/mL =99.2	NA
DDS2	Newmeyer et al.	2017	134	18-50	Healthy users*	Edible	OF and Blood (LCMS/MS)	≥ 25 ng/mL ≥ 10 ng/mL ≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥0.2 ng/mL	≥ 25 ng/mL =95.5 ≥ 10 ng/mL =96.0 ≥ 5 ng/mL=96.8 ≥ 2 ng/mL =61.7 ≥ 1 ng/mL =61.7 ≥0.2 ng/mL =44.1	≥ 25 ng/mL =79.5 ≥ 10 ng/mL =81.7 ≥ 5 ng/mL=86.4 ≥ 2 ng/mL =90.5 ≥ 1 ng/mL =90.5 ≥0.2 ng/mL =92.7	NA
DDS2	Edwards et al.	2017	104	18-72	subjects arrested for (OWI)	NA	Blood (Enzyme Immunoassay)	25 ng/mL	88.37	86.89	87.5 PPV: 82.61 NPV: 91.34
DT5000	Swortwood et al.	2017	551	18-50	Healthy Users*	Multiple**	OF (LCMS/MS)	≥ 5 ng/mL ≥ 2 ng/mL ≥1 ng/mL ≥0.2 ng/mL	≥ 5 ng/mL: 80.0 ≥ 2 ng/mL: 66.3 ≥1 ng/mL: 57.5 ≥0.2 ng/mL: 36.9	≥ 5 ng/mL: 91.9 ≥ 2 ng/mL: 96.8 ≥1 ng/mL: 98.7 ≥0.2 ng/mL: 99.3	NA
DT5000	Newmeyer et al.	2017	103	18-50	Healthy Users*	Edible	OF and Blood (LCMS/MS)	≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥ 0.2 ng/mL	≥ 5 ng/mL =89.3 ≥ 2 ng/mL =50.0 ≥1 ng/mL =50.0 ≥0.2 ng/mL =34.9	≥ 5 ng/mL =94.7 ≥ 2 ng/mL =97.9 ≥1 ng/mL =97.9 ≥0.2 ng/mL =100	NA
DT5000	Hartman et al.	2015	43	21-42	Healthy users*	Vaporizer	OF (2D-GCMS)	5 ng/mL 2 ng/mL 1 ng/mL	5 ng/mL: 64.9 2 ng/mL: 53.8 1 ng/mL: 48.7	5 ng/mL: 97.2 2 ng/mL: 99.3 1 ng/mL: 100	5 ng/L: 77.5 2 ng/L: 65.0 1 ng/L: 57.1
DT5000	Huestis et al.	2013	24	18-45	Healthy users*	Smoked	OF (2D-GCMS)	2 ng/mL 1 ng/mL	2 ng/mL: 75.3 1 ng/mL: 66.4	2 ng/mL: 94.1 1 ng/mL: 98.9	2 ng/mL: 81.8 1 ng/mL: 73.9
DrugWipe5A	Gentili et al.	2016	83	NA	Subjects in a social setting (e.g. bars)	NA	OF (HS-SPME-GC, MS- EIO)	30 ng/mL	29	88	53

Note: Studies that tested multiple populations and devices may appear more than once. DT5000=Drager™ DrugTest 5000; DDS2= Alere™ DDS2; OF=Oral Fluid; LC-MS/MS=Liquid chromatography – tandem mass spectrometry; 2D-GCMS=Two dimensional gas chromatography-mass spectrometry; HS-SPME-GC=Headspace-Solid Phase Microextraction-Gas Chromatography; MS-EIO= mass spectrometry, electron impact ionization; OWI=operating while intoxicated; *Healthy cannabis users in a laboratory setting; ** multiple routes refers to exposure by controlled smoking, vaporizing, and edible routes in a laboratory setting. The limit of quantitation (LOQ) was 0.2 ng/mL.

Table 3. Sensitivity and Specificity of Point of Collection Oral Fluid Cannabis Exposure Screening Devices, by Cannabis Use Frequency

Device(s)	Study	Year	N	Age	Population	Exposure route	Comparison Matrix/Method	Cut off value(s)	Sensitivity	Specificity
DDS2	Swortwood et al.	2017	345	18-50	Frequent users	Multiple	OF (LCMS/MS)	≥ 25 ng/mL ≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥0.2 ng/mL	≥ 25 ng/mL =98.0 ≥ 5 ng/mL =85.6 ≥ 2 ng/mL =64.0 ≥ 1 ng/mL =51.6 ≥0.2 ng/mL =37.0	≥ 25 ng/mL =82.7 ≥ 5 ng/mL =93.1 ≥ 2 ng/mL =97.9 ≥ 1 ng/mL =98.7 ≥0.2 ng/mL =100
DDS2	Newmeyer et al.	2017	72	18-50	Frequent users	Edible	OF and Blood	≥ 25 ng/mL ≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥0.2 ng/mL	≥ 25 ng/mL =100 ≥ 5 ng/mL=100 ≥ 2 ng/mL =58.8 ≥ 1 ng/mL =58.8 ≥0.2 ng/mL =37.0	≥ 25 ng/mL =86.7 ≥ 5 ng/mL=94.5 ≥ 2 ng/mL =100 ≥ 1 ng/mL =100 ≥0.2 ng/mL =100
DT5000	Swortwood et al.	2017	300	18-50	Frequent users	Multiple	OF (LCMS/MS)	≥ 5 ng/mL ≥ 2 ng/mL ≥1 ng/mL ≥0.2 ng/mL	≥ 5 ng/mL =79.1 ≥ 2 ng/mL =65.0 ≥1 ng/mL =56.6 ≥0.2 ng/mL =39.5	≥ 5 ng/mL =89.5 ≥ 2 ng/mL =97.9 ≥1 ng/mL =100 ≥0.2 ng/mL =100
DT5000	Newmeyer et al.	2017	60	18-50	Frequent users	Edible	OF and Blood	≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥ 0.2 ng/mL	≥ 5 ng/mL =82.4 ≥ 2 ng/mL =43.2 ≥1 ng/mL =43.2 ≥0.2 ng/mL =30.4	≥ 5 ng/mL =93.0 ≥ 2 ng/mL =95.7 ≥1 ng/mL =95.7 ≥0.2 ng/mL =100
DDS2	Swortwood et al.	2017	200	18-50	Occasional users	Multiple	OF (LCMS/MS)	≥ 25 ng/mL ≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥0.2 ng/mL	≥ 25 ng/mL =100 ≥ 5 ng/mL =82.0 ≥ 2 ng/mL =67.7 ≥ 1 ng/mL =57.3 ≥0.2 ng/mL =35.4	≥ 25 ng/mL =86.2 ≥ 5 ng/mL =96.7 ≥ 2 ng/mL =97.1 ≥ 1 ng/mL =97.6 ≥0.2 ng/mL =98.6
DDS2	Newmeyer et al.	2017	62	18-50	Occasional users	Edible Cannabis	OF and Blood	≥ 25 ng/mL ≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥0.2 ng/mL	≥ 25 ng/mL =90.0 ≥ 5 ng/mL=92.9 ≥ 2 ng/mL =65.4 ≥ 1 ng/mL =65.4 ≥0.2 ng/mL =53.8	≥ 25 ng/mL =71.2 ≥ 5 ng/mL=77.1 ≥ 2 ng/mL =80.6 ≥ 1 ng/mL =80.6 ≥0.2 ng/mL =87.0
DT5000	Swortwood et al.	2017	251	18-50	Occasional users	Multiple	OF (LCMS/MS)	≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥0.2 ng/mL	≥ 5 ng/mL =82.9 ≥ 2 ng/mL =70.8 ≥1 ng/mL =60.3 ≥0.2 ng/mL =31.5	≥ 5 ng/mL =94.0 ≥ 2 ng/mL =96.1 ≥1 ng/mL =97.9 ≥0.2 ng/mL =99.2
DT5000	Newmeyer et al.	2017	43	18-50	Occasional users	Edible	OF and Blood	≥ 5 ng/mL ≥ 2 ng/mL ≥ 1 ng/mL ≥ 0.2 ng/mL	≥ 5 ng/mL =100 ≥ 2 ng/mL =63.2 ≥1 ng/mL =63.2 ≥0.2 ng/mL =44.4	≥ 5 ng/mL =96.9 ≥ 2 ng/mL =100 ≥1 ng/mL =100 ≥0.2 ng/mL =100

Note: Studies that tested multiple populations and devices may appear more than once. Table reflects same studies and participants as prior table stratified by frequency of cannabis use. Accuracy not available in these studies for these subpopulations. DT5000=Drager™ DrugTest 5000; DDS2= Alere™ DDS2; OF=Oral Fluid; LC-MS/MS=liquid chromotography-tandem mass spectrometry; The limit of quantitation (LOQ) was ~ 0.2 ng/mL.

Chronic Frequent Users versus Occasional Users

Table 3 shows the results from studies testing the accuracy of the OF POCT devices, grouped by participant cannabis use history (e.g. frequent user vs. occasional) and by device. This table reflects the two key studies found by our search that differentiated results based on the participants' cannabis use history. These are the same studies as reported above, but broken out for the subpopulations included rather than overall results.

Swortwood's study for the DDS did not show substantially different performance (e.g. more than few percentage points) between chronic vs. frequent users at a 25ng/ML or 5ng/mL confirmation cutoff. In both groups, sensitivity approached 100% for the 25ng/mL cutoff, and sensitivity was 82%-86%. The same study suggested that at the 5ng/ML cutoff, the DT5000 had a sensitivity of 79.1 for frequent users vs. 82.9 for occasional users; specificity of 89.5 for frequent users vs. 94.0 for occasional users. In their study of smoked cannabis, Huestis et al. report that the sensitivity of the DT5000 was was 6-11% higher in frequent as compared to occasional cannabis users and suggest that this was due to having a longer detection windows and higher true positive rates (Huestis et al., 2013; Huestis et al., 2013). The DDS performed slightly better that the DT5000 among frequent users at the 5ng/mL cutoff in the two original studies we reviewed that directly compared the devices. Taking all evidence into account, both devices perform reasonably well for both frequent and occasional users.

Edible Route of Exposure

As shown in Table 3, the DT5000, in a study that focused only on edible cannabis, had a sensitivity of 64.9% and specificity of 97.2%, for an overall accuracy of 77.5% (Hartman et al., 2015). A smaller study found a sensitivity of 89.3 and specificity of 94.7. This is in contrast to the DDS2 which, in the smaller study, had a sensitivity of 96.8 and specificity of 86.5. The DT5000 may perform slightly better than the DDS2 when edible cannabis has been consumed, as its specificity was higher (96.9% vs. 77.1%) in the study by Newmeyer and colleagues that focused on the edible route of exposure (Newmeyer et al., 2017a).

Vaporized Route of Exposure

Hartman and colleagues (2015) reported that the DT5000 showed sensitivity of 64.9, specificity of 97.2, and efficiency of 77.5% after vaporized cannabis, using the 5ng/mL confirmatory cutoff (Hartman et al., 2015). These authors noted that cannabis vapor may interact with oral mucosa differently to smoke, altering the performance of the POCT (Hartman et al., 2015). While the sensitivity in this study was reduced due to false negatives compared to other studies that tested the device after smoked or edible routes of administration, the high specificity indicates that false positives were rare.

POC Urine Testing

One study returned by our searches evaluated POTC urine tests, the EZ Cup and the Multi4Card (Kim et al., 2017). The study utilized commercially available samples (Detectabuse) and information about the individuals who originally provided the samples was not available. The cut-off value for these tests was 50 ng/mL of THC-COOH. The results were assessed on a grading scale (G2-G4) where lower grade meant a higher drug concentration for confirmation testing. The EZ Cup had a sensitivity ranging from 98.5 (G2) to 100 (G4) and a specificity ranging from 93.0 (G2) to 53.0 (G4). The Multi4Card had a sensitivity range from 6.0 (G2) to 92.0 (G4) and a specificity range from 99.2 (G2) to 87.7 (G4). The EZ cup had with consistently low false negative tests, but, as concentration decreased, there were more false positives. The EZ Cup therefore exhibited better performance, but it is important to note that the inactive metabolite THC-COOH can be detected for days to weeks after cannabis administration (Goodwin et al., 2008) and a positive screening result alone (absent other information) does not permit inference regarding time of cannabis use.

Other Considerations

Across all studies, authors note that frequent smokers had significantly later median t_{last} (time of last cannabis detection) compared to occasional smokers. This means that frequent marijuana users may show positive results on POCT results for longer after cannabis administration compared to occasional users who used the same amount.

The studies described here utilize THC as the confirmation marker of cannabis exposure. Hartman (2015) and colleagues note that THC-COOH has been proposed as a potential additional confirmatory criterion, to be used with THC because it helps rule out passive environmental exposure, detects oral cannabis use, and can extend detection windows in chronic frequent cannabis smokers (Lee et al., 2011; Moore et al., 2011). However, in Hartman's study of vaporized cannabis, THCCOOH was not always detected; including THCCOOH as a requirement for confirmation decreased sensitivity. At this point, the use of additional metabolites as a confirmatory method with POCT devices is not firmly established in the literature.

Research Question 3a: Cognitive and Behavioral Effects Relevant to Driving

We reviewed 29 studies that contained information about the cognitive and behavioral indicators of marijuana exposure that are relevant to operating a motor vehicle. The study designs utilized can be grouped into four categories: laboratory studies, studies conducted in a driving simulator, on-road studies, and observational studies. The cognitive and behavioral effects of marijuana that relate to driving fall into three domains which include automotive behavior, control behavior, and executive function/planning. These domains were described in Walsh's 2008 Guidelines for Research on Drugged Driving (Walsh et al., 2008). Based on the literature we obtained through our search, for the purpose of this review, we address an additional behavioral domain which is driving performance/safety. Table 4 describes the domains and provides examples of tasks/tests that measure them.

Multiple effects may be measured in one study, and different study designs are well-suited to evaluate different types of effects. For example, only the simulator and on-road studies can address driving performance and safe driving. We also considered the elements of the standardized field sobriety test (SFST) which is reflective of control behavior. The SFST includes activities such as a one leg stand, walk and turn, and the modified Romberg balance test.

Table 4. Domains of Driving-Related Cognitive and Behavioral Effects of Marijuana

Domain	Definition	Example Tasks Used for Measurement
Automative Behavior*	Well-learned skills	• Tracking, steering (road tracking, critical tracking, compensatory tasks). • Vigilance or sustained attention (e.g. Mackworth Clock Test).
Control Behavior*	Maintaining distance, passing, etc.	• Motor performance, maneuvers (reaction time, car following tasks). • Divided attention (dual attention tasks). • Perception (time to collision-type tasks).
Executive Function/Executive Planning *	Interactive functions with ongoing traffic.	• Risk taking, impulsivity (e.g. stop signal, Iowa gambling tasks). • Information processing, attention (choice, reaction time, selective or focused attention tasks). • Cognition, judgement
Driving performance/safety	Appropriate and safe operation of a vehicle	• Maintaining proper headway • Lane positioning • Speed and braking
Note: *Definitions from Walsh et al. 2008 "Guidelines for Research on Drugged Driving"		

Automative Behavior

In lab-based studies, we found evidence for 15 different measurements of automotive behavior across 6 studies. For frequent users, 5 out of 6 saw no effect, and 1 found hurt performance, although it must be noted that two of these studies included low doses of cannabis. For occasional users, 5/5 tests indicated that marijuana hurt performance. In 4 studies in which the population cannabis use history was not specified, both low and medium dose administration resulted in generally worse task performance (3/4). Two simulator studies that included measurement of automative behavior both found decreased performance after marijuana administration.

Table 5. Assessments of the Impact of Cannabis Exposure on Automative Behavior

Study	Study Type	n	User Population	THC Dosage (Route)	Brief description	Result*	Magni-tude of Result*	Study Quality**
Weinstein et al. 2008	Lab	14	Frequent	13 and 17 mg	Virtual Maze task	HP	NA	SS, NT
Desroisers et al. 2015	Lab	25	Frequent	6.80%	CTT	NE	NA	SS
Shwope et al. 2012	Lab	10	Frequent	6.80%	CTT	NE	NA	LD, SS
Shwope et al. 2012	Lab	10	Frequent	6.80%	Divided Attention Task	NE	NA	LD, SS
Ramaekers et al. 2011	Lab	21	Frequent	(~28mg)	Tracking Task	NE	NA	SS, LD,
Ramaekers et al. 2009	Lab	12	Frequent	~35mg)	CTT	NE	NA	SS
Sexton et al. 2000	Lab	15	NS	1.7% - 2.67%	Critical Tracking Task	HP	NA	SS, LD, UP
Ramaekers et al. 2006	Lab	20	NS	17.5mg (4%)	Tracking Task	HP	NA	SS, LD, UP
Ramaekers et al. 2006	Lab	20	NS	35mg (13%)	Tracking Task	HP	NA	SS, UP
Sexton et al. 2000	Lab	15	NS	1.7% - 2.67%	Critical Tracking Task	NE	NA	SS, LD UP
Desroisers et al. 2015	Lab	25	Occasional	6.80%	CTT	HP	NA	SS
Batistella et al. 2013	Lab	31	Occasional	42mg	CTT	HP	NA	SS
Batistella et al. 2013	Lab	31	Occasional	42mg	FMRI (tracking)	HP	NA	SS
Batistella et al. 2013	Lab	31	Occasional	42mg	FMRI (target & cursor)	HP	NA	SS
Ramaekers et al. 2009	Lab	12	Occasional	~35mg	CTT	HP	NA	SS
Papafotiou et al. 2005	Sim.	40	NS	14mg & 52mg	Tracking Task	HP	NA	UP
Menetrey et al. 2005	Sim.	8	Occasional	16.5mg & 45.7mg (oral)	Tracking Task	HP	NA	SS, NT

Note: NS=not specified; CTT=critical tracking task; *Result classified as: HP=hurt performance, IP=improved performance, NE=no effect. Magnitude of results only provided if statically significant. ** Issues potentially impacting study quality were noted as: SS=small sample size; NT = no validated tool used; LD = low dose marijuana, UP=user population not defined, DR= use of subjective high with no dose response gradient; OT=other quality issues. Sim.= Driving simulator study.

Control Behavior

In 18 lab-based measurements of control behavior, 11 focused on frequent or not specified user population, and 4 observed poorer performances after marijuana administration, 1 with improved performance, and 6 with no effect. Of note, the largest study had 136 participants and demonstrated poorer performance. Among tests in occasional users, 6/7 demonstrated poorer performance with one demonstrating no effect. Simulator-based studies showed an even split between hurt performance and no effect. In three on-road studies, control behavior, and specifically reaction time, was not impacted.

In lab studies, 9/9 tests that used elements of the SFST to assess control behavior among frequent users demonstrated no effect. In occasional users, this was 3/9. And in two observational studies that together accounted for results on seven tests of control behavior as measured with a SFST, decreased performance was noted in all tests, though it must be noted that the study design did not allow assessment of most potential limitations.

Executive Function and Planning

In 16 tests of executive function among frequent cannabis users, six hurt performance and 10 showed no effect. Among occasional users, six hurt performance, and six showed no effect. For non-specified users, 9/10 studies showed hurt performance. These results indicate more evidence for decreased executive function regardless of use history, with about half or more of the studies finding decreased performance.

Driving Performance and Safety

In simulator studies, mean speed decreased in 6/14 studies conducted among occasional users. We did not characterize decreased speed as either an improvement or detriment to driving performance, since in a real-world environment this behavior could be associated either with safer driving or with an increased crash risk, depending on the circumstance. There were three studies with decreased performance, including on a measure of collisions, and all other results showed no effect. In two studies that did not specify the cannabis use history of participants, there was decreased performance on 5/7 measures. These included mean headway and lateral position, and speed measures. In 10 driving performance tasks conducted in on-road studies of occasional users, the authors observed impaired performance for five tasks and no effect for five tasks.

Table 6. Assessments of the Impact of Cannabis Exposure on Control Behavior

Study	Study Type	n	User Population	THC Dosage (Route)	Brief description	Result	Result Magnitude*	Study Quality
Ramaekers et al. 2000	On-road	18	NS	100 and 200 ng/kg	Reaction time	NE	NA	SS, UP
Robbe et al. 1998 # 2	On-road	16	Occasional	100, 200, 300 ng/kg	Reaction time	NE	NA	SS
Robbe et al. 1998 # 4	On-road	18	Occasional	100 and 200 ng/kg	Reaction time	NE	NA	SS
Lenne et al. 2009	Simulator	47	NS	19mg & 38mg	Sign detection task	HP	NA	UP
Sexton et al. 2000	Simulator	15	NS	1.7% & 2.6%	Reaction time task	NE	NA	SS, UP
Ronen et al. 2010	Simulator	12	Occasional	13mg	Arithmetic Task	HP	NA	SS, NT
Ronen et al. 2007	Simulator	14	Occasional	13mg & 17mg	Reaction time test - Computerized	HP	S	SS, NT
Rafaelsen et al. 1973	Simulator	8	Occasional	200, 300, 400mg	Reaction Time	HP	NA	SS
Anderson et al. 2010	Simulator	85	Occasional	22.9mg	Paced Auditory Serial-Addition Test [PASAT]	HP	M	
Anderson et al. 2010	Simulator	85	Occasional	22.9mg	Emergency Vehicle Avoidance Task	NE	NA	
Anderson et al. 2010	Simulator	85	Occasional	22.9mg	Dog and intersection Incursion Task, PASAT Task, Emergency vehicle avoidance task	NE	NA	
Anderson et al. 2010	Simulator	85	Occasional	22.9mg	Emergency Vehicle Avoidance Task	NE	NA	
Metrik et al. 2012	Lab	136	Frequent	2.80%	Stroop test	HP	M	LD
Hart et al. 2001	Lab	18	Frequent	1.8% & 3.9%	Repeated Acquisition Task (Computerized)	HP	NA	SS, LD
Ramaekers et al. 2011	Lab	21	Frequent	~28mg	Divided Attention Task	HP	NA	SS, LD
Theunissen et al. 2012	Lab	24	Frequent	13%	Electro Cap / Neuro Scan Software	HP	S	SS
Hart et al. 2001	Lab	18	Frequent	1.8% & 3.9%	Divided Attention Task	IP	NA	SS, LD
Shwope et al. 2012	Lab	10	Frequent	6.80%	DAT - Computerized	NE	NA	LD, SS
Shwope et al. 2012	Lab	10	Frequent	6.80%	DAT - Computerized	NE	NA	LD, SS
Theunissen et al. 2012	Lab	24	Frequent	13%	DAT - Computerized	NE	NA	SS
Ramaekers et al. 2009	Lab	12	Frequent	~35mg	Divided Attention Task	NE	NA	SS
Desroisers et al. 2015	Lab	25	Frequent	6.80%	Divided Attention Task	NE	NA	SS
Theunissen et al. 2012	Lab	24	Frequent	13%	Electro Cap / Neuro Scan Software	HP	M	SS
Chiat 1994	Lab	14	NS	3.60%	Time Production Test	NE	NA	SS, LD, UP
Chiat 1994	Lab	14	NS	3.60%	Divided Attention Task	NE	NA	SS, LD, UP
Desroisers et al. 2015	Lab	25	Occasional	6.80%	Divided Attention Task	HP	NA	SS
Theunissen et al. 2012	Lab	24	Occasional	13%	DAT - Computerized	HP	S	SS
Theunissen et al. 2012	Lab	24	Occasional	13%	Electro Cap / Neuro Scan Software	HP	S	SS
Theunissen et al. 2012	Lab	24	Occasional	13%	Electro Cap / Neuro Scan Software	HP	S	SS
Ramaekers et al. 2009	Lab	12	Occasional	~35mg	Divided Attention Task	HP	NA	SS

Note: DAT=divided attention task; *Result classified as: HP=hurt performance, IP=improved performance, NE=no effect. Magnitude of results only provided if statically significant. ** Issues potentially impacting study quality were noted as: SS=small sample size; NT = no validated tool used; LD = low dose marijuana, UP=user population not defined, DR= use of subjective high with no dose response gradient; OT=other quality issues.

Table 7. Assessments of the Impact of Cannabis Exposure on Executive Function and Planning Behavior

Study	Study Type	n	User Population	THC Dosage (Route)	Brief description	Result	Result Magnitude*	Study Quality
Metrik et al. 2012	Lab	136	Frequent	2.80%	Stop Signal Task	HP	M	LD
Weinstein et al. 2008	Lab	14	Frequent	13 and 17 mg	Wisconsin Card Sorting Task	HP	NA	SS, NT
Weinstein et al. 2008	Lab	14	Frequent	13 and 17 mg	Gambling Task	HP	M	SS, NT
Theunissen et al. 2012	Lab	24	Frequent	500 ng/kg (13%)	Stop Signal Task - computerized	HP	M	SS
Ramaekers et al. 2009	Lab	12	Frequent	500ng/kg (~35mg)	Stop Signal Task	HP	NA	SS
Hart et al. 2001	Lab	18	Frequent	1.8% & 3.9%	Digit Recall Task (Computerized)	HP (3.9%)	NA	SS, LD
Vadhan et al. 2006	Lab	36	Frequent	1.8 & 3.9%	Gambling Task	NE	NA	LD, DR
Desroisers et al. 2015	Lab	25	Frequent	6.80%	n-back task	NE	NA	SS
Desroisers et al. 2015	Lab	25	Frequent	6.80%	Balloon Analog Task	NE	NA	SS
Sewell et al. 2012	Lab	44	Frequent	0.015 - 0.05 mg/kg	Time Estimation	NE	NA	LD, DR
Hart et al. 2001	Lab	18	Frequent	1.8% & 3.9%	Digit Symbol Substitution Task	NE	NA	SS, LD
Weinstein et al. 2008	Lab	14	Frequent	13 and 17 mg	Novel TP task	NE	NA	SS, NT
Ramaekers et al. 2011	Lab	21	Frequent	400 ng/kg (~28mg)	Stop Signal Task	NE	NA	SS, LD
Ramaekers et al. 2011	Lab	21	Frequent	400 ng/kg (~28mg)	Tower of London Task	NE	NA	SS, LD
Ramaekers et al. 2009	Lab	12	Frequent	500ng/kg (~35mg)	Tower of London Task	NE	NA	SS
Chiat 1994	Lab	14	NS	3.60%	Backward Digit Span	HP	NA	SS, LD, UP
Ramaekers et al. 2006	Lab	20	NS	17.5mg (4%)	Stop Signal Task	HP	NA	SS, LD, UP
Ramaekers et al. 2006	Lab	20	NS	17.5mg (4%)	Tower of London Task	HP	NA	SS, LD, UP
Ramaekers et al. 2006	Lab	20	NS	17.5mg (4%)	Gambling task	HP	NA	SS, LD, UP
Ramaekers et al. 2006	Lab	20	NS	35mg (13%)	Stop Signal Task	HP	NA	SS, UP
Ramaekers et al. 2006	Lab	20	NS	35mg (13%)	Tower of London Task	HP	NA	SS, UP
Ramaekers et al. 2006	Lab	20	NS	35mg (13%)	Gambling task	HP	NA	SS, UP
Chiat 1994	Lab	14	NS	3.60%	Digit Symbol Substitution Task	NE	NA	SS, LD, UP
Lane et al. 2005	Lab	10	NS	1.77% & 3.5%	Computerized gambling ask	HP	S	SS, LD, UP
Desroisers et al. 2015	Lab	25	Occasional	6.80%	n-back task	NE	NA	SS
Desroisers et al. 2015	Lab	25	Occasional	6.80%	Balloon Analog Task	NE	NA	SS
Sewell et al. 2012	Lab	44	Occasional	0.015 - 0.05 mg/kg	Time Estimation Software 2.0	HP	M	LD, DR
MacDonald et al. 2003	Lab	37	Occasional	15mg (Oral)	Verbal Digit Span Task	HP	NA	
MacDonald et al. 2003	Lab	37	Occasional	15mg (Oral)	time perception task	HP	NA	
MacDonald et al. 2003	Lab	37	Occasional	15mg (Oral)	Computerized Stop Signal Task	HP	NA	
Theunissen et al. 2012	Lab	24	Occasional	500 ng/kg (13%)	Stop Signal Task - computerized	HP	S	SS
Ramaekers et al. 2009	Lab	12	Occasional	500ng/kg (~35mg)	Stop Signal Task	HP	NA	SS
MacDonald et al. 2003	Lab	37	Occasional	15mg (Oral)	Delay Discounting Task	NE	NA	SS, LD
Ramaekers et al. 2009	Lab	12	Occasional	500ng/kg (~35mg)	Tower of London Task	NE	NA	SS
MacDonald et al. 2003	Lab	37	Occasional	15mg (Oral)	Hopkins Verbal Recall Task	NE	NA	
MacDonald et al. 2003	Lab	37	Occasional	15mg (Oral)	Verbal Go no go task	NE	NA	

Note: DAT=divided attention task; *Result classified as: HP=hurt performance, IP=improved performance, NE=no effect. Magnitude of results only provided if statically significant. ** Issues potentially impacting study quality were noted as: SS=small sample size; NT = no validated tool used; LD = low dose marijuana, UP=user population not defined, DR= use of subjective high with no dose response gradient; OT=other quality issues.

Research Question 3b: Field Measurement of Marijuana’s Effects and Accuracy for Determining Impairment

Laboratory based measurement of marijuana’s cognitive and behavioral effects are described above. While there are many tools used to measure the domains of impairment in laboratory settings, as evidenced in Tables 5-7, field measures lag behind.

In the peer reviewed literature, we identified three studies testing SFST for detecting marijuana impairment. Accuracy was, at best approximately 50% for the one leg stand portion of the test. We also conducted a web search that identified several mobile applications that offer versions of some of the tests for automative behavior, executive function, and control behavior that were measured above, as being impacted by marijuana. Although only one tool: DRUID (Milburn, 2017), was developed explicitly for measuring marijuana-related effects, these tools in general may have promise. DRUID is being tested in an NIH-funded study at Brown University Medical School.

Table 8. Field Tests for Cognitive and Behavioral Indicators of Marijuana Effects, Peer-Reviewed Literature

Tool Type	**Tested for MJ**	**Study**	**Year**	**Accuracy for MJ Impairment**	**Overall Result**
SFST	Yes	Porath-Waller and Beirness	2014	Classification Rate: HGN: 1% OLS: 55.4%* WAT: 39.7%	Cannabis adversely affected performance on the OLS test but not the WAT and HGN tests
SFST	Yes	Bosker et al.	2012	HGN: 15% OLS: 50%* WAT: 35%	Cannabis significantly impaired performance on the OLS
SFST	Yes	Papafotiou	2005	Overall SFST Battery: Time 1 (5 min post smoking): 46.2% Time 2 (55 min post smoking): 41% Time 3 (105 min post smoking): 28.2%	The results indicated that the consumption of cannabis containing either 1.74% THC or 2.93% THC impaired performance on the SFSTs.

Notes: HGN=horizontal gaze nystagmus; WAT=Walk and Turn: OLS= one leg stand

Table 9. Field Tests of Cognitive and Behavioral Indicators of Marijuana's Effects, Non-Peer Reviewed

Tool Type	Tool Name	Designed for MJ	Relates to R3A Task Category / Test	URL	Notes
Mobile App	DRUID	Yes	Automotive behavior; Executive function; Control behavior o Reaction time o Decision making o Tracking o Time estimation	https://www.druidapp.com	"DRUID is currently being tested in a NIH-funded study at the Brown University Medical School."
Mobile App	Brain Turk	No	Automotive behavior; Control behavior o Go -no go task o N Back task o Tracking o Digit tasks o Wisconsin card sorting task o Gambling / risk taking task o Recall tasks o Arithmetic task o Audio vision matching o Complex working memory o Advertises 40+ games / available tests on mobile app	https://www.brainturk.com/games	Advertised as cognitive games. Not meant to assess exposure to MJ. Included given mobile availability of many of the task category tests identified in RQ3A
Mobile App	Encephal-app	No	Control behavior - Stroop Test	http://www.encephalapp.com	Not meant to assess exposure to MJ. Included given mobile availability of task category tests identified in RQ3A
Mobile App	CANTAB	No	Control behavior -Stop Signal Task - Gamblling Task	http://www.cambridgecognition.com/cantab/	Not meant to assess exposure to MJ. Included given mobile availability of task category tests identified in RQ3A
Mobile App	Brain Baseline	No	Control behavior -Stroop Test - N-Back	https://itunes.apple.com/us/app/brainbaseline/id408975136?mt=8	Not meant to assess exposure to MJ. Included given mobile availability of task category tests identified in RQ3A

Discussion

Well-established laboratory methods for quantifying marijuana exist and offer high sensitivity and specificity for measurement of delta-9-THC. Among the most popular techniques currently in use are chromatographic methods such as gas chromatography mass spectrometry (GC-MS) and liquid chromatography with tandem mass spectrometry (LC-MS/MS). In relation to quantifying exposure, the absence of ability to discern potentially key pieces of information from measuring THC alone however has spurred interest in the utility of THC metabolite quantification. The phase-two THC metabolite (THC-Glucuronide) as well as cannabigerol (CBG), cannabinol (CBN), and tetrahydrocannabivarin (THCV) offer promise in discerning recency of use and movement of metabolites to alternative matrices (Huestis & Smith, 2018). As research related to marijuana metabolism continues to advance, such inferences may prove useful in efforts to establish legal driving limits and standards. Despite this promise however, the inability to quantify THC metabolites in a field setting remains a chief limitation.
This review identified two point-of-collection devices with substantial evidence that they perform with sensitivity and specificity above 80% at a confirmation cut-point of 5ng/mL. The DT5000 has a slightly lower sensitivity and higher specificity; the DDS2 has a slightly higher sensitivity and lower specificity. Most screening tests require tradeoffs between these two aspects of correct identification. A higher sensitivity reduces false negatives (i.e. a cannabis user with delta-9-THC above the cut-off who screens negative); a higher specificity reduces false positives (e.g. an individual with a delta-9-THC level below the cut-off who screens positive). Choice between the two devices should depend upon the specific use case and consequences of misclassification. The findings from this study indicate that OF devices may be effective for use in field settings with reasonable accuracy.

For context, recent studies showed that after smoking or vaporizing cannabis in a controlled environment, chronic frequent users maintained blood THC levels of 25 ng/mL for an average of ~ 30-45 minutes. By ~6-10 hours, levels have fallen to 5 ng/mL and at 72 hours post smoking, blood THC levels remained between 5 ng/mL and the LOQ (1 ng/mL) (Newmeyer et al., 2016). Frequent users that orally ingested cannabis in a controlled environment showed similar long term pharmacokinetic profiles, with blood THC levels between 5 ng/mL and the LOQ (1 ng/mL) 72 hours post ingestion. However, average peak concentrations were lower (~25ng/mL) and average time to peak concentration (~ 3-4 hours) was greater with average blood levels remaining under 10 ng/mL leading up to the peak (Newmeyer et al., 2017a; Newmeyer et al., 2016).

In occasional users, THC blood levels in controlled environments after smoking and vaporization peaked on average in ~10 minutes and stayed above 25 ng/mL for ~30 minutes. At approximately one hour, THC levels remained close to 5 ng/mL but by ~ 3 hours on average, THC blood levels had fallen below the LOQ and by ~ 12-15 hours, THC was undetectable (Newmeyer et al., 2016). Blood THC levels of occasional users ingesting THC in a controlled environment followed a similar peaking pattern to that of frequent users. On average, concentrations did not peak until ~ 3 hours post ingestion.

However, by ~ 5 hours blood THC levels had fallen below 5ng/mL and by ~ 11 hours, THC was not detectable in the blood (Newmeyer et al., 2016).

Blood cannabinoid concentration cannot be estimated from OF data (Newmeyer et al., 2017b). The studies reviewed indicated that for smoked and vaporized cannabis, OF and blood THC concentrations were significantly correlated for up to 8 hours cannabis administration (Hartman et al., 2016), with THC concentrations in both matrices peaking during or shortly after use followed by rapid decreases. Edible cannabis, however, displays a different profile with OF THC C_{max} (maximum concentration) occurring by 0.3 hours, while blood THC C_{max} occurs 1-5 hours later. These different pharmacokinetic time courses explain the lack of correlation between OF and blood concentrations during the first 5 h after edible cannabis (Newmeyer et al., 2017b). Thus, the route of cannabis administration has a large impact on how well oral fluid correlates with blood THC. At present, most marijuana users smoke or vaporize marijuana, making oral fluid testing a reasonable option, though other routes of administration may become more frequent as retail sales of adult use marijuana begin in Massachusetts.

The evidence suggests that marijuana has cognitive and behavioral effects in the areas of automative behavior, especially for occasional users, and there also are likely some executive function impacts for some users. In simulated road environments, marijuana exposure was associated with decreased speed; which may be either positive or negative for driving performance and crash risk, depending on the circumstance. Marijuana exposure also unquestionably hurt driving performance in some ways. The overall picture was one of mixed results that on balance fall between no effect and decreased performance. It is worth noting that when reported, magnitude of impaired performance was generally small. In controlled environments, the marijuana use was not associated with performance decreases on elements of the standardized field sobriety test, though observational studies reached a different conclusion.

References

Alcohol and Drug Abuse Institute. (2013). What is Cannabis? Retrieved from http://learnaboutmarijuanawa.org/factsheets/whatiscannabis.htm.

Alere DDS®2 Mobile Test System: Rapid Screening for Drugs of Abuse in Oral Fluid. (2018). Retrieved from https://www.alere.com/en/home/product-details/dds2-mobile-test-system.html#.

Allen, K. R. (2011). Screening for drugs of abuse: which matrix, oral fluid or urine? *Annals of Clinical Biochemistry, 48*(6), 531-541.

Arnett, J. J., & Tanner, J. L. (Eds.). (2004). *Emerging Adulthood: The Winding Road from the Late Teens through the Twenties*. New York, NY: Oxford University Press.

Arria, A. M., Caldeira, K. M., Vincent, K. B., Garnier-Dykstra, L. M., & O'Grady, K. E. (2011). Substance-related traffic-risk behaviors among college students. *Drug Alcohol Depend, 118*(2-3), 306-312. doi:10.1016/j.drugalcdep.2011.04.012

Asbridge, M., Hayden, J. A., & Cartwright, J. L. (2012). Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. *BMJ, 344*, e536.

Banta-Green, C., Rowhani-Rahbar, A., Ebel, B. E., Andris, L. M., & Qiu, Q. (2016). Cannabis Use among Drivers Suspected of Driving Under the Influence or Involved in Collisions: Analyses of Washington State Patrol Data.

Berning, A., & Smither, D. (2014). *Understanding the Limitations of Drug Test Information, Reporting, and Testing Practices in Fatal Crashes*. Washington, D.C.: U. S. D. o. Transportation.

Blencowe, T., Pehrsson, A., & Lillsunde, P. (2010). *Analytical evaluation of oral fluid screening devices and preceding selection procedures*. A. a. M. Driving Under the Influence of Drugs. Retrieved from https://www.bast.de/Druid/EN/deliverales-list/downloads/Deliverable_3_2_2.pdf?__blob=publicationFile&v=1.

Bondallaz, P., Favrat, B., Chtioui, H., Fornari, E., Maeder, P., & Giroud, C. (2016). Cannabis and its effects on driving skills. *Forensic Sci Int, 268*, 92-102. doi:https://doi.org/10.1016/j.forsciint.2016.09.007.

Bosker, W. M., & Huestis, M. A. (2009). Oral fluid testing for drugs of abuse. *Clin Chem, 55*(11), 1910-1931.

Chihuri, S., Li, G., & Chen, Q. (2017). Interaction of marijuana and alcohol on fatal motor vehicle crash risk: a case-control study. *Inj Epidemiol, 4*(1), 8. doi:10.1186/s40621-017-0105-z.

Compton, R. (2017). *Marijuana-Impaired Driving A Report to Congress*. Washington, DC.

Davis, K. C., Allen, J., Duke, J., Nonnemaker, J., Bradfield, B., Farrelly, M. C., . . . Novak, S. (2016). Correlates of Marijuana Drugged Driving and Openness to Driving While High: Evidence from Colorado and Washington. *PLoS One, 11*(1), e0146853. doi:10.1371/journal.pone.0146853.

Department of Health and Environment, C. Adult marijuana use trends. *Monitoring trends in adult marijuana use.*

Department of Health and Human Services. (2015). *Mandatory Guidelines for Federal Workplace Drug Testing Programs*.

Dräger DrugTest® 5000: Analysis system for detecting drugs. (2018). Retrieved from https://www.draeger.com/Library/Content/drugtest_5000_pi_9041006_en.pdf.

Drummer, O. H. (2010). Forensic toxicology. *Exs, 100*, 579-603.

Edwards, L. D., Smith, K. L., & Savage, T. (2017). Drugged Driving in Wisconsin: Oral Fluid Versus Blood. *J Anal Toxicol, 41*(6), 523-529. doi:10.1093/jat/bkx051.

Gentili, S., Solimini, R., Tittarelli, R., Mannocchi, G., & Busardo, F. P. (2016). A Study on the Reliability of an On-Site Oral Fluid Drug Test in a Recreational Context. *J Anal Methods Chem, 2016*, 1234581. doi:10.1155/2016/1234581.

Gentili, S., Solimini, R., Tittarelli, R., Mannocchi, G., & Busardò, F. P. (2016). A Study on the Reliability of an On-Site Oral Fluid Drug Test in a Recreational Context. *J Anal Methods Chem, 2016*, 1234581. doi:10.1155/2016/1234581.

Goodwin, R. S., Darwin, W. D., Chiang, C. N., Shih, M., Li, S.-H., & Huestis, M. A. (2008). Urinary elimination of 11-nor-9-carboxy-delta9-tetrahydrocannnabinol in cannabis users during continuously monitored abstinence. Journal of analytical toxicology, 32(8), 562-569.

Grotenhermen, F. (2003). Pharmacokinetics and pharmacodynamics of cannabinoids. *Clin Pharmacokinet, 42*(4), 327-360. doi:10.2165/00003088-200342040-00003.

Gunasekaran, N., Long, L. E., Dawson, B. L., Hansen, G. H., Richardson, D. P., Li, K. M., . . . McGregor, I. S. (2009). Reintoxication: the release of fat-stored Δ(9)-tetrahydrocannabinol (THC) into blood is enhanced by food deprivation or ACTH exposure. *British Journal of Pharmacology, 158*(5), 1330-1337. doi:10.1111/j.1476-5381.2009.00399.x.

Hartman, R. L., Anizan, S., Jang, M., Brown, T. L., Yun, K. M., Gorelick, D. A., . . . Huestis, M. A. (2015). Cannabinoid disposition in oral fluid after controlled vaporizer administration with and without alcohol. *Forensic Toxicology, 33*(2), 260-278. doi:10.1007/s11419-015-0269-6.

Hartman, R. L., Brown, T. L., Milavetz, G., Spurgin, A., Gorelick, D. A., Gaffney, G., & Huestis, M. A. (2016). Controlled vaporized cannabis, with and without alcohol: subjective effects and oral fluid-blood cannabinoid relationships. *Drug Test Anal, 8*(7), 690-701. doi:10.1002/dta.1839.

Hoffman, J. (2016). Study finds sharp increase in marijuana exposure among Colorado children. *The New York Times*. Retrieved from https://www.nytimes.com/2016/07/26/health/marijuana-edibles-are-getting-into-colorado-childrens-hands-study-says.html.

Hollister, L. E., Gillespie, H. K., Ohlsson, A., Lindgren, J. E., Wahlen, A., & Agurell, S. (1981). Do plasma concentrations of delta 9-tetrahydrocannabinol reflect the degree of intoxication? *J Clin Pharmacol, 21*(8-9 Suppl), 171s-177s.

Huestis, M. A. (2002). Cannabis (Marijuana) - Effects on Human Performance and Behavior. *Forensic Sci Rev, 14*(1-2), 15-60.

Huestis, M. A. (2007). Human Cannabinoid Pharmacokinetics. *Chemistry & biodiversity, 4*(8), 1770-1804. doi:10.1002/cbdv.200790152.

Huestis, M. A., Milman, G., Mendu, D., Lee, D., Barnes, A. J., Schwope, D., . . . Desrosier, N. A. (2013). *Evaluation the on-site Draeger DrugTest 5000 in occasional and chronic frequent smokers following controlled cannabis smoking*. Retrieved from http://www.icadtsinternational.com/files/documents/2013_058.pdf.

Huestis, M. A., Milman, G., Mendu, D., Lee, D., Barnes, A. J., Schwope, D. M., . . . Desrosiers, N. A. (2013). *Evaluation of the on-site Draeger DrugTest 5000 in occasional and chronic frequent smokers following controlled cannabis smoking.* Paper presented at the International Conference on Alcohol, Drugs and Traffic Safety (T2013), 20th, 2013, Brisbane, Queensland, Australia.

Huestis, M. A., & Smith, M. L. (2018). Cannabinoid Markers in Biological Fluids and Tissues: Revealing Intake. *Trends Mol Med, 24*(2), 156-172. doi:10.1016/j.molmed.2017.12.006.

Kim, S. Y., Kim, H., Park, Y., Lim, J., Kim, J., Koo, S. H., & Kwon, G. C. (2017). Evaluation of an Automated Reader and Color Interpretation-Based Immunoassays for Multiplexed Drug-of-Abuse Testing in Urine. *J Anal Toxicol, 41*(5), 412-420. doi:10.1093/jat/bkx014.

Lee, D., Milman, G., Barnes, A. J., Goodwin, R. S., Hirvonen, J., & Huestis, M. A. (2011). Oral fluid cannabinoids in chronic, daily cannabis smokers during sustained, monitored abstinence. *Clin Chem, 57*(8), 1127-1136.

Li, G., Chihuri, S., & Brady, J. E. (2017). Role of alcohol and marijuana use in the initiation of fatal two-vehicle crashes. *Annals of Epidemiology, 27*(5), 342-347.e341. doi:https://doi.org/10.1016/j.annepidem.2017.05.003.

Li, K., Simons-Morton, B., Gee, B., & Hingson, R. (2016). Marijuana-, alcohol-, and drug-impaired driving among emerging adults: Changes from high school to one-year post-high school. *J Safety Res, 58*, 15-20. doi:10.1016/j.jsr.2016.05.003.

Macdonald, S., Anglin-Bodrug, K., Mann, R. E., Erickson, P., Hathaway, A., Chipman, M., & Rylett, M. (2003). Injury risk associated with cannabis and cocaine use. *Drug Alcohol Depend, 72*(2), 99-115.

Milburn, M. (2017). DRUID. Retrieved from https://www.druidapp.com.

Moore, C., Coulter, C., Uges, D., Tuyay, J., Van der Linde, S., Van Leeuwen, A., . . . Orbita Jr, J. (2011). Cannabinoids in oral fluid following passive exposure to marijuana smoke. *Forensic Sci Int, 212*(1-3), 227-230.

National Highway Traffic Safety Administration. (2016a). *2016 FARS/CRSS Coding and Validation Manual*. Washington, D.C: National Highway Traffic Safety Administration. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812449.

National Highway Traffic Safety Administration. (2016b). *Fatality Analysis Reporting System (FARS) Analytical User's Manual 1974-2015*. Washington, D.C.: U. S. D. o. Transportation. Retrieved from http://www.nber.org/fars/ftp.nhtsa.dot.gov/fars/FARS-DOC/Analytical%20User%20Guide/USERGUIDE-2015.pdf.

Newmeyer, M. N., Swortwood, M. J., Andersson, M., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2017a). Cannabis Edibles: Blood and Oral Fluid Cannabinoid Pharmacokinetics and Evaluation of Oral Fluid Screening Devices for Predicting Delta9-Tetrahydrocannabinol in Blood and Oral Fluid following Cannabis Brownie Administration. *Clin Chem, 63*(3), 647-662. doi:10.1373/clinchem.2016.265371.

Newmeyer, M. N., Swortwood, M. J., Andersson, M., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2017b). Cannabis Edibles: Blood and Oral Fluid Cannabinoid Pharmacokinetics and Evaluation of Oral Fluid Screening Devices for Predicting Delta(9)-Tetrahydrocannabinol in Blood and Oral Fluid following Cannabis Brownie Administration. *Clin Chem, 63*(3), 647-662. doi:10.1373/clinchem.2016.265371.

Newmeyer, M. N., Swortwood, M. J., Barnes, A. J., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2016). Free and Glucuronide Whole Blood Cannabinoids' Pharmacokinetics after Controlled Smoked, Vaporized, and Oral Cannabis Administration in Frequent and Occasional Cannabis Users: Identification of Recent Cannabis Intake. *Clin Chem, 62*(12), 1579-1592. doi:10.1373/clinchem.2016.263475.

Quantisal™ Oral Fluid Collection Device. (2018). Retrieved from https://www.alere.com/en/home/product-details/QuantisalOralFluidCollectionDevice-au.html.

Rocky Mountain High Intensity Drug Trafficking Area. (2015). The Legalization of Marijuana in Colorado: The Impact.

Rogeberg, O., & Elvik, R. (2016). The effects of cannabis intoxication on motor vehicle collision revisited and revised. *Addiction, 111*(8), 1348-1359. doi:10.1111/add.13347.

Salomonsen-Sautel, S., Min, S. J., Sakai, J. T., Thurstone, C., & Hopfer, C. (2014). Trends in fatal motor vehicle crashes before and after marijuana commercialization in Colorado. *Drug Alcohol Depend, 140*, 137-144. doi:10.1016/j.drugalcdep.2014.04.008.

Scherer, J. N., Fiorentin, T. R., Borille, B. T., Pasa, G., Sousa, T. R. V., von Diemen, L., . . . Pechansky, F. (2017). Reliability of point-of-collection testing devices for drugs of abuse in oral fluid: A systematic review and meta-analysis. *Journal of Pharmaceutical and Biomedical Analysis, 143*, 77-85. doi:10.1016/j.jpba.2017.05.021.

Subramanian, R. (2002). *Transitioning to multiple imputation - A New method to estimate missing blood alcohol concentration (BAC) in FARS*. Springfield, VA: National Center for

Statistics and Analysis. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809403.
Swortwood, M. J., Newmeyer, M. N., Abulseoud, O. A., Andersson, M., Barnes, A. J., Scheidweiler, K. B., & Huestis, M. A. (2017). On-site oral fluid Delta(9)-tetrahydrocannabinol (THC) screening after controlled smoked, vaporized, and oral cannabis administration. *Forensic Toxicology, 35*(1), 133-145. doi:10.1007/s11419-016-0348-3.
Tefft, B. C., Arnold, L. S., & Grabowski, J. G. (2016). Prevalence of Marijuana Involvement in Fatal Crashes: Washington, 2010–2014.
Verstraete, A., Knoche, A., Jantos, R., Skopp, G., Gjerde, H., Vindenes, V., . . . Lillsunde, P. (2011). Per se limits: methods of defining cut-off values for zero tolerance.
Wall, M. E., Sadler, B. M., Brine, D., Taylor, H., & Perez-Reyes, M. (1983). Metabolism, disposition, and kinetics of delta-9-tetrahydrocannabinol in men and women. *Clin Pharmacol Ther, 34*(3), 352-363.
Walsh, J. M. (2008). New technology and new initiatives in US workplace testing. *Forensic Sci Int, 174*(2-3), 120-124. doi:10.1016/j.forsciint.2007.03.011
Walsh, J. M., Verstraete, A. G., Huestis, M. A., & Mørland, J. (2008). Guidelines for research on drugged driving. *Addiction, 103*(8), 1258-1268.
Wang, G. S., Roosevelt, G., Le Lait, M. C., Martinez, E. M., Bucher-Bartelson, B., Bronstein, A. C., & Heard, K. (2014). Association of unintentional pediatric exposures with decriminalization of marijuana in the United States. *Ann Emerg Med, 63*(6), 684-689. doi:10.1016/j.annemergmed.2014.01.017.
Westin, A. A., Mjønes, G., Burchardt, O., Fuskevåg, O. M., & Slørdal, L. (2014). Can Physical Exercise or Food Deprivation Cause Release of Fat-Stored Cannabinoids? *Basic & Clinical Pharmacology & Toxicology, 115*(5), 467-471. doi:10.1111/bcpt.12235.
Whitehill, J. M., Rivara, F. P., & Moreno, M. A. (2014). Marijuana-using drivers, alcohol-using drivers, and their passengers: prevalence and risk factors among underage college students. *JAMA Pediatr, 168*(7), 618-624. doi:10.1001/jamapediatrics.2013.5300.
Wong, A., Keats, K., Rooney, K., Hicks, C., Allsop, D. J., Arnold, J. C., & McGregor, I. S. (2014). Fasting and exercise increase plasma cannabinoid levels in THC pre-treated rats: an examination of behavioural consequences. *Psychopharmacology (Berl), 231*(20), 3987-3996. doi:10.1007/s00213-014-3532-3.
Wong, A., Montebello, M. E., Norberg, M. M., Rooney, K., Lintzeris, N., Bruno, R., . . . McGregor, I. S. (2013). Exercise increases plasma THC concentrations in regular cannabis users. *Drug Alcohol Depend, 133*(2), 763-767. doi:10.1016/j.drugalcdep.2013.07.031
Wood, E., Brooks-Russell, A., & Drum, P. (2016). Delays in DUI blood testing: Impact on cannabis DUI assessments. *Traffic Inj Prev, 17*(2), 105-108. doi:10.1080/15389588.2015.1052421.
World Health Organization. (2017). Adolescent Health. Retrieved from http://www.who.int/topics/adolescent_health/en/.
Zou, G. (2004). A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol, 159*(7), 702-706.

Chapter 2: Driving Under the Influence of Marijuana and Marijuana-Involved Motor Vehicle Crashes in Massachusetts

Introduction

Experimental research suggests that marijuana (cannabis) use impairs functions related to safe driving (Huestis, 2002). Epidemiological evidence for the increase in the magnitude of motor vehicle crash risk from marijuana use ranges from 22% to 100% (a doubling) (Asbridge et al., 2012; G. Li et al., 2017; Rogeberg & Elvik, 2016). In studies of Colorado adults (Davis et al., 2016) as well as college students (Whitehill, Rivara, & Moreno, 2014), and high school students (K. Li, Simons-Morton, Gee, & Hingson, 2016), driving under the influence of marijuana (DUI-marijuana) is common among marijuana users. These individuals, as well as passengers who ride with a driver under the influence of marijuana (RUI-marijuana), would experience any increased risk for involvement in a motor vehicle crash that exists when the driver has used marijuana.

As Massachusetts implements legal retail marijuana sales for all adults, it is important to understand the prevalence of driving under the influence of marijuana and riding with a marijuana-using driver prior to the start of retail marijuana sales for non-medical use among adults age 21 and over. These topics are not well- measured in other Massachusetts datasets that have been previously collected for other purposes. Such information will be necessary to measure the extent to which there are changes in the prevalence of these events after retail adult-use marijuana sales are implemented. Another useful "baseline" measure related to marijuana and motor vehicle crashes is how frequently crash-involved drivers test positive for marijuana. Although such testing does not indicate that the driver was intoxicated by or impaired by marijuana at the time of the crash, such data nonetheless provides some information on information relevant to maintaining safe roadways, such as the extent to which drivers are tested for cannabinoids and cannabinoid disposition among drivers.

This chapter describes two studies related to driving and marijuana use. First, we present an analysis of data from the statewide population survey conducted as part of the MBHS that addresses DUI-marijuana and RUI-marijuana. Second, we present an analysis of Massachusetts data from the Fatality Analysis Reporting System which includes information on fatal crashes (i.e. crashes in which one occupant died within 30 days of the crash) and the state's Crash Data System which includes information on all crashes on Massachusetts roadways.

Methods

Population survey of Massachusetts adults

We conducted a population-based, mail and Internet survey of Massachusetts residents age 18 years and older. This study was approved by the Institutional Review Board at the Massachusetts Department of Public Health. A copy of the survey instrument can be found in Appendix A. Details on the methods of survey design, data collection, measures, and statistical procedures, including survey weighting, can be found in Task 1, Chapter 2 of this Marijuana Baseline Health Study report. In addition to the measures described therein, several questions were added to the survey for the purpose of addressing DUI-marijuana and RUI-marijuana.

Measures

DUI-marijuana was assessed with the item “During the past 30 days, how many times have you driven a car or other motor vehicle while you were under the influence of marijuana?” Response options included 0 times, 1 time, 2-3 times, 4-5 times, or 6 or more times. RUI-marijuana was ascertained with the question “During the past 30 days, how many times did you ride as a passenger in a car or other motor vehicle when the driver was under the influence of marijuana” with the same response options as listed above.
Parallel questions were asked for alcohol and other substances. We also asked about driving after the concurrent use of multiple substances with response options that included: marijuana and alcohol, marijuana and other drugs, alcohol and other drugs, or marijuana, alcohol, and other drugs.

Statistical analysis

Please see the methods section in Chapter 2, Task 1 for details on weighting and statistical procedures for this survey. As noted therein, a total of 3,268 non-duplicate survey questionnaires were returned with 212 determined ineligible. After screening for completion and eligibility, there were a total of 3,023 eligible surveys. The logic-checking process resulted in identification of 1 case in which multiple questions had unreasonable responses. This case was dropped, resulting in a final analytic sample of 3,022.
Several variables relevant to this chapter were re-coded from the original data. DUI-marijuana was dichotomized as a yes/no variable indicating any driving under the influence of marijuana in the past 30 days. RUI-marijuana was similarly dichotomized. Frequency of marijuana use in the past 30 days was categorized as a 3-level variable (0 days, 1-20 days, 21 or more days). Frequency of alcohol use, originally measured in days per week, was categorized as a 3-level variable (0 days, 1-4 days, 5-7 days).

First, we examined bivariate differences in driving under the influence of substances and riding with a substance-using driver between adults who had used marijuana in the past 30 days and those who had not. Next, we examined bivariate differences in socio-demographics and substance use behavior by DUI-marijuana and RUI-marijuana status. Differences were tested with chi-squared tests for categorical variables. Finally, to assess which factors were associated with DUI-marijuana and RUI-marijuana, we estimated relative risk (RR) using Poisson regression with robust standard errors (Zou, 2004). We examined associations between driving under the influence of marijuana (yes/no) and age, gender, race/ethnicity, education, frequent marijuana use, alcohol use, and riding under the influence of marijuana. When variables were not significant in initial models they were not retained in the final model, with the exception of age, gender, and race, and alcohol use. We used a similar multivariable regression approach with RUI-marijuana as the dependent variable. We used a two-tailed significance level at $p < 0.05$ for all statistical tests. All analyses were weighted and were conducted using commands that accounted for the complex survey design, yielding results that are adjusted to be representative of the adult population in Massachusetts. The analysis for this report was generated using SAS/STAT software, Version 9.4 of the SAS System for Windows (Copyright © 2016 SAS Institute Inc. Cary, NC, USA.) with the exception of the regression models which were generated using Stata 15 statistical software (StataCorp, LLC, College Station, TX).

Fatality Analysis Reporting System (FARS)

To estimate the prevalence of marijuana, alcohol and other drug use by drivers in fatal crashes, 11 years of data (2006-2016) from the Fatality Analysis Reporting System (FARS) were studied. FARS is a national database maintained by the states and administered by the National Highway Traffic Safety Administration (NHTSA). It contains detailed information on every person and vehicle involved in a fatal crash in 26 linkable datasets. The various datasets are compiled at the state level; a state FARS analyst coordinates with the various agencies to gather the necessary data. For example, the police will provide information on the crash (manner of collision, time, location, etc.) and the medical examiner will provide toxicology information (blood alcohol content, presence of drugs, etc.).

For this analysis, two FARS datasets were utilized, the “Person” and “Accident” files. The “Person” file contains an entry for each individual involved in a fatal crash whether they are the driver, a passenger, or a non-motorist. This dataset contains information such as demographics, seating position, drug and alcohol test results. The “Accident” file contains crash level information such as time and location of the crash, manner of collision and overall number of fatalities. A full list of fields and datasets can be found in the FARS Analytical User’s Manual (National Highway Traffic Safety Administration, 2016).

Measures

From the FARS “Accident” dataset only the field reflecting the number of fatalities resulting from the crash (FATALS) was used. All other variables came from the FARS “Person” dataset, which included an indicator of “person type” which denotes whether the person was a driver, passenger or non-motorist (PER_TYP). We used an indicator of injury severity to identify individuals who died in a crash.

Demographic measures

The FARS fields for the person’s age, sex, and race/ethnicity were included in this analysis. Within FARS, race is only coded for deceased persons. There are 18 options for race and an additional six options that indicate whether the person was of Hispanic/Latino descent. The available categories were condensed into five categories: White, non-Hispanic; Black, non-Hispanic; Asian, non-Hispanic; Other, non-Hispanic; and any Hispanic/Latino.

Cannabis and other drug measures

FARS includes information on the type of drug testing conducted stored in three variables (DRUGTST1/ DRUGTST2/ DRUGTST3). Persons involved in a fatal crash can have up to three types of drug tests (e.g. blood, urine, etc.) recorded in FARS in these fields. Also included are up to three results from the reported drug tests (DRUGRES1/ DRUGRES2/ DRUGRES3). The DRUGRES fields report a code to indicate the specific drugs detected, although the level of drug concentrations are not available within the dataset. There are over 600 different drug types and an exhaustive list can be found in the 2016 FARS/CRSS Coding and Validation Manual (National Highway Traffic Safety Administration, 2016).

This analysis focused upon cannabinoids which are indicated in FARS with the following codes:

- 600 – Delta 9
- 601 – Hashish Oils
- 602 – Hashish
- 603 – Marijuana/Marihuana
- 604 – Marinol
- 605 – Tetrahydrocannabinols (THC)
- 695 – Cannabinoid, Type Unknown

A summary variable was created to indicate whether a drug test result was positive for any of the seven cannabinoid codes listed above. Delta-9-THC is a primary psychoactive compound from the cannabis plant that contributes to the ‘high’ that users experience. As described in Chapter 1, it is metabolized in the body into other cannabinols that can be detected in laboratory testing but are not necessarily psychoactive. Generally, delta-9-THC is measurable in blood for a shorter duration after marijuana use than other metabolites, but this is complicated by individual characteristics such as frequency of cannabis use. Prior studies of marijuana involvement in crashes using FARS data in other states tend to focus on delta-9-THC because it is associated with the effects of cannabis (Tefft et al., 2016). However, it is important to note that driver *impairment* in the crash cannot be discerned from values of delta-9-THC or other compounds. Delta-9-THC, when present, is generally indicative of recent marijuana use.
Two years of FARS data (2011 and 2012) appeared anomalous in that there were near-zero levels of code 600 indicating a positive test for Delta-9-THC among drivers given a blood test for drugs. This was inconsistent with other years of Massachusetts FARS data in this analysis and inconsistent with published reports of FARS data from other states (Grondel, Hoff, & Doane, 2018). This absence of code 600 for delta-9-THC in two years of FARS data is likely to be a result of data collection or data entry practices and not indicative of true rates. Additionally, in the 11 years of Massachusetts data, there were only two recorded cases of a person testing positive for codes 601, 602, 603, or 604. In light of these potential irregularities in the cannabis codes observed in FARS, we

report on the presence of “any cannabinoid” which, though less specific than the code for delta-9-THC, appeared more reliable.

Alcohol measures

The presence of alcohol in a person is recorded in two fields within the FARS database. ATST_TYP reports the type of alcohol test given (blood, breath, etc.) and ALC_RES indicates the results of alcohol testing such as the blood alcohol content obtained from the given alcohol test. Due to problems that arise from missing data, blood alcohol content (BAC), estimates of alcohol-impaired driving are typically reported after NHTSA uses a multiple imputation process for cases in which testing was not conducted or reported (Subramanian, 2002). Imputation was not used in the present study for alcohol because the focus was on marijuana-involved crashes. NHTSA does not presently have a standardized imputation procedure for cannabis-related test results, although such procedures are being developed and tested with promising results (Chen, Williams, Liu, Chihuri, & Li, 2018). To facilitate comparison across substances within this report, only known BAC values were used in this analysis. The estimates in this report for fatalities with alcohol involvement, therefore, may not match the publicly available estimates which incorporate imputed BAC values.

Analysis

The total number of fatal crashes, number of fatally-injured persons, number of fatal crash-involved drivers, and number of deceased drivers were tabulated. Numbers and percentages of drivers who received a blood test for alcohol or drugs were calculated and graphed, as appropriate. Numbers and proportions of drivers testing positive for any cannabinoid, by driver sex, race/ethnicity, and age, and the extent to which cannabinoids were found in conjunction with alcohol, and with other drugs were calculated.

Crash Data System (CDS)

In addition to FARS, the Massachusetts Crash Data System (CDS) was utilized to examine trends in frequency of marijuana-related crashes. Unlike FARS, CDS contains every reported motor vehicle crash, and not just crashes with a fatality. However, CDS is based on the Massachusetts crash report form which is completed by the police officer who responded to the crash. This crash report form does not contain the same level of detail as FARS; it does not contain any fields related to known or suspected drug use.

As an alternative to a specific drug use field, the crash narrative was utilized. The crash narrative is a free form field where the responding officer can include any information they felt to be important that couldn’t be captured within the existing crash report fields. A query was written which identified crash reports which had a crash narrative containing the keywords “marijuana”, “weed”, and “cannabis”. The keywords “high” and “pot” were originally queried as well but these resulted in a high rate of false positives so they were excluded from the final query.

While it is not possible to determine how many non-fatal crashes occurred which involved marijuana, the aforementioned method provides insight into the number of crashes in which the responding officer suspected marijuana involvement.

Results

Population survey of Massachusetts adults

Sample Characteristics

The demographic patterns of survey respondents by reported marijuana use in the past 30 days are provided in Table 1. In reporting survey results, all estimates are weighted and all percentages represent population estimates.

Table 1. Select sample demographics. Reproduced from Task 1, Chapter 2, Table 1

	Used marijuana in past 30 days			Did not use marijuana in past 30 days			Total		
	n=439 (21.1%)			n=2583 (76.4%)					
	Weighted %	95% CI		Weighted %	95% CI		Weighted %	95% CI	
Gender									
Female	42.3	35.6	48.9	55.5	52.7	58.4	52.7	50.0	55.4
Male	57.7	51.1	64.4	44.5	41.6	47.3	47.3	44.6	50.0
Age									
18-20	9.6*	4.2	15.0	2.2	0.8	3.6	3.8*	2.1	5.4
21-25	14.7	9.5	20.0	4.2	2.5	5.8	6.4	4.7	8.1
26-29	14.3	9.1	19.6	7.4	5.5	9.2	8.9	7.0	10.7
30-39	18.1	13.1	23.2	16.8	14.4	19.1	17.0	14.9	19.2
40-49	15.5	10.0	20.9	17.6	15.2	19.9	17.1	15.0	19.3
50=59	15.3	11.8	18.9	18.0	16.1	19.9	17.5	15.8	19.1
60-69	10.1	7.2	13.1	16.7	15.0	18.4	15.3	13.8	16.8
>=70	2.3	0.6*	3.9	17.2	15.5	18.9	14.0	12.6	15.4
Education									
High school or less	38.4	31.1	45.7	31.9	28.8	34.9	33.2	30.4	36.1
College	53.1	46.1	60.1	48.8	45.9	51.6	49.7	47.0	52.4
Graduate school	8.5	6.1	10.9	19.4	17.6	21.1	17.1	15.5	18.6
Ethnicity									
Hispanic	12.0	7.0	16.9	8.7	6.4	10.9	9.4	7.3	11.4
White, non-Hispanic	70.8	64.0	77.7	75.4	72.6	78.3	74.5	71.8	77.1
Black, non-Hispanic	7.1*	2.7	11.6	5.5	4.0	7.0	5.8	4.3	7.4
Asian, non-Hispanic	3.2*	0.7	5.7	7.3	5.6	9.0	6.4	5.0	7.8
Other, non-Hispanic	6.9	3.1	10.7	3.1	2.1	4.1	3.9	2.8	5.0
Region									
Boston	13.8	9.0	18.6	14.3	12.1	16.4	14.2	12.2	16.2
Central	13.3	9.1	17.5	14.6	12.7	16.4	14.3	12.6	16.0
Metrowest	18.3	12.6	24.0	22.1	19.8	24.5	21.3	19.1	23.6
Northeast	17.4	12.3	22.4	18.4	16.2	20.7	18.2	16.1	20.3
Southeast	18.8	12.9	24.6	18.9	16.7	21.1	18.9	16.8	21.0
Western	18.5	13.7	23.3	11.6	10.0	13.3	13.1	11.4	14.7
Note: * denotes fewer than 25 respondents; table reproduced from Task 1, Chapter 2.									

Prevalence of driving under the influence and riding with a substance-using driver

Among the estimated 21.1% of the adult population that used marijuana, the prevalence of driving under the influence of marijuana in the past 30 days was 34.3% (Table 2). Overall, 7.2% of the adult population drove under the influence of marijuana in the past 30 days. For assessment of RUI-marijuana, both non-users and users of marijuana were considered to have engaged in the behavior if they reported riding as a passenger with a driver that is under the influence of marijuana. Results show that 11.3% of Massachusetts adults rode with a marijuana-using driver in the past 30 days. The proportion who RUI-marijuana was statistically significantly higher among marijuana users (36.7%) compared to non-users (4.2%) [$p<0.001$].

We found that 6.9% of the population drove under the influence of alcohol (DUI-alcohol) and 7.9% of all adults rode as a passenger with a driver under the influence of alcohol (Table 2). Marijuana users were more likely to report DUI-alcohol (15.2%) compared to non-users (4.7%) ($p<0.001$) and to report RUI-alcohol (14.6%) compared to non-users (6.1%) ($p<0.001$).
Subpopulation prevalence

By age, we found that 25.6% of young adults age 18-20 years reported driving under the influence of marijuana, and 24.1% of those age 21-25 years. The proportion of adults in each age group who drove after marijuana use subsequently drops off among older age groups. (Table 3). Among females, 5.5% reported DUI-marijuana, which was statistically significantly less than the percentage of males reporting DUI-marijuana (9.1%) ($p=0.04$).

We observed that as the number of days per month of marijuana use increases, the proportion of individuals who drive under the influence of marijuana also increases. Among individuals who use marijuana 21 days per month or more, just over 50% reported DUI-marijuana.

By age, we also found that nearly 36% of 18-20 year old adults reported riding with a marijuana-using driver in the past 30 days. Prevalence was 38% among those age 21-25 years, then lower for older age groups (Table 3). We did not observe a difference by gender or race/ethnicity. Prevalence of RUI-marijuana was lowest among those with a post-graduate degree (5.7%).
A higher proportion of those who drove under the influence of marijuana reported riding as a passenger with marijuana-using driver (67.5%) compared to marijuana users who did not drive under its influence (21.2%) ($p<0.001$) (Table 4). We found that 42.8% of individuals who drove under the influence of marijuana reported driving under the influence of alcohol and marijuana, used simultaneously

Table 2. Prevalence of driving under the influence of alcohol, marijuana, or other substances and riding with a substance-using driver, Massachusetts adults, 2017

	Marijuana users n=439			Marijuana non-users n=2583			Total n=3022			
	%	95% LCI	95% UCI	%	95% LCI	95% UCI	%	95% LCI	95% UCI	P-value
Past 30-day behaviors										
Drove under the influence of marijuana	34.3	27.6	41.0	.	.	.	7.2	5.5	8.8	
Rode with driver under influence of marijuana	36.7	29.9	43.6	4.2	2.8	5.7	11.3	9.2	13.4	<0.001
Drove under the influence of alcohol	15.2	10.3	20.2	4.7	3.4	5.9	6.9	5.5	8.4	<0.001
Rode with a driver under influence of alcohol	14.6	10.1	19.1	6.1	4.9	7.3	7.9	6.5	9.3	<0.001
Drove under the influence of other substances	0.9	0.1	1.7	0.5	0.1	1.0	0.6	0.2	1.0	0.440
Rode with a driver under the influence of other substances	2.3	0.7	3.9	1.1	0.4	1.9	1.4	0.7	2.0	0.205
Drove under influence of any substance	37.2	30.4	44.0	5.0	3.7	6.3	11.8	9.9	13.8	<0.001
Rode with driver under the influence of any substance	42.2	35.2	49.2	10.2	8.4	12.0	17.0	14.8	19.3	<0.001

Table 3. Past 30-day prevalence of DUI-marijuana and RUI-marijuana, by demographic group

	Drove under the influence of marijuana				Rode with a driver who was under the influence of marijuana			
	%	95% LCL	95% UCL	p-value	%	95% LCL	95% UCL	p-value
Overall	7.2	5.5	8.8		11.3	9.2	13.4	
Age								
18-20	25.6*	5.5	45.6	0.002	35.8	14.2	57.5	<0.001
21-25	24.1	12.3	35.8		38.0	24.5	51.6	
26-34	11.7	6.8	16.5		18.1	12.0	24.3	
35-64	4.5	3.0	6.0		7.7	5.6	9.7	
65+	1.1	0.3	1.9		1.4	0.5	2.4	
Gender								0.600
Female	5.5	3.6	7.5	0.042	11.9	9.1	14.7	
Male	9.1	6.3	11.8		10.8	7.7	13.9	
Ethnicity								
Any Hispanic	11.5	3.5	19.6	0.139	18.4	8.8	28.0	0.390
White, non-Hispanic	6.9	5.1	8.7		10.3	8.1	12.4	
Black, non-Hispanic	1.9*	0.0	4.3		15.0	2.7	27.4	
Asian, non-Hispanic	3.5*	0.0	7.5		8.3	2.0	14.6	
Other, non-Hispanic	16.2	2.9	29.4		13.5	0.5	26.6	
Education								0.027
High school or less	7.0	3.4	10.5	0.009	11.4	6.9	15.9	
College	9.4	7.0	11.7		13.5	10.7	16.4	
Graduate school	2.2	0.8	3.5		5.7	3.3	8.1	
# days using marijuana, past 30 days								0.032
1-5 days	17.9	9.6	26.1		21.2	11.9	30.4	
6-10 days	17.8	2.8	32.7		36.9	15.4	58.5	
11-15 days	45.4	21.2	69.6		52.9	28.3	77.5	
16-20 days	47.1	21.6	72.5		45.3	19.5	71.2	
21 or more days	53.6	41.7	65.4		49.4	37.4	61.4	

* Based on small cell size of 5 or fewer. Percentages are row percents.

Characteristics of individuals who drive under the influence of marijuana (DUI-marijuana)

Table 4 also shows characteristics and substance use behaviors of marijuana users who drove under the influence of marijuana compared to those who did not. We found no differences in the distribution of gender or ethnicity by DUI-marijuana status. Of those who drove under the influence of marijuana, 47.1% did so six or more times in the past 30 days, 32.7% did so 2-5 times, and 17% did so just once. Of these individuals, 67.5% also rode with a driver who was under the influence of marijuana once or more in the past 30 days; 8% did so only one time.

Table 4. Demographic characteristics by driving under the influence among adult marijuana users

	Drove under the influence of marijuana n=129			Did not drive under the influence of marijuana n=302			Total marijuana users n=439			
	%	95% LCI	95% UCI	%	95% LCI	95% UCI	%	95% LCI	95% UCI	P-value
Age										
18-20	13.3 *	2.3	24.4	7.8	1.9	13.8	9.7	4.2	15.2	0.185
21-25	21.3	10.9	31.7	11.6	5.6	17.5	14.9	9.6	20.3	
26-29	11.9	5.1	18.7	15.9	8.6	23.2	14.5	9.2	19.9	
30-39	23.0	12.5	33.5	16.0	10.5	21.4	18.4	13.2	23.5	
40-49	12.2	4.0	20.4	17.2	10.1	24.4	15.5	10.0	21.0	
50=59	11.7	6.6	16.7	17.4	12.6	22.2	15.5	11.8	19.1	
60-69	5.7	2.6	8.9	12.4	8.2	16.6	10.1	7.1	13.1	
>=70	0.9*	0.0	1.8	1.6	0.7	2.6	1.4	0.7	2.1	
Gender										
Female	40.5	28.7	52.3	42.6	34.4	50.8	41.9	35.2	48.6	0.771
Male	59.5	47.7	71.3	57.4	49.2	65.6	58.1	51.4	64.8	
Ethnicity										
Any Hispanic	15.1	4.9	25.3	10.6	5.1	16.1	12.1	7.1	17.2	0.277
White, non-Hispanic	71.5	59.6	83.3	71.1	62.7	79.6	71.2	64.4	78.1	
Black, non-Hispanic	1.6*	0.0	3.5	10.1	3.4	16.7	7.1	2.6	11.7	
Asian, non-Hispanic	3.0*	0.0	6.6	2.1*	0.0	4.7	2.5	0.4	4.5	
Other, non-Hispanic	8.8	1.0	16.6	6.1	1.8	10.4	7.0	3.1	10.9	
Frequency of DUI Marijuana										
0 times	.	.	.	100.0	100.0	100.0	65.7	59.0	72.4	
once	17.0	8.9	25.2	.	.	.	5.9	2.9	8.8	
2-3 times	30.0	18.3	41.8	.	.	.	10.3	5.6	15.0	
4-5 times	2.7	0.7	4.7	.	.	.	0.9	0.3	1.6	
6 or more	47.1	34.9	59.3	.	.	.	16.2	10.8	21.5	
yes, frequency unknown	3.1*	0.0	6.1	.	.	.	1.0	0.0	2.1	
Rode with driver under influence of marijuana	67.5	56.4	78.6	21.2	13.6	28.7	37.1	30.2	44.1	<0.001

Frequency of RUI-Marijuana										
0 times	32.5	21.4	43.6	78.8	71.3	86.4	62.9	55.9	69.8	<0.001
once	8.0	3.2	12.9	7.6	3.4	11.8	7.8	4.5	11.0	
2-3 times	30.2	18.2	42.3	8.5	2.1	14.9	16.0	9.9	22.1	
4-5 times	6.2	0.4	12.1	3.2	0.4	6.1	4.3	1.5	7.0	
6 or more	23.0	12.8	33.2	1.8	0.5	3.2	9.1	5.2	13.0	
DUI- alcohol	46.8	33.8	59.8	3.7	1.4	6.0	18.8	12.9	24.8	<0.001
RUI -alcohol	19.3	11.0	27.5	12.5	7.0	18.0	14.8	10.2	19.4	0.175
DUI- combined alcohol and marijuana	42.8	27.7	57.9	.	.	.	16.0	9.0	23.1	-

Note: Table displays column percentages. DUI-=Drove under the influence; RUI-marijuana=Rode as a passenger with a driver under the influence.*based on ≤25 responses

Among those who used both marijuana and alcohol in the past 30 days, 46.8% of those who drove under the influence of marijuana also drove under the influence of alcohol. In comparison, users of both marijuana and alcohol who did not drive under the influence of marijuana had a much lower prevalence of driving under the influence of alcohol, at only 3.7%.

Characteristics of individuals who ride with driver under the influence of marijuana (RUI-marijuana)

Table 5 shows a comparison of demographic and substance use characteristics between individuals who rode with a driver under the influence of marijuana and those who did not. The distribution of RUI-marijuana by age showed that higher proportions of younger individuals tended to engage in this behavior versus older individuals. . Most individuals (70.6%) who RUI-marijuana had used marijuana in the past 30 days; this is in contrast to 15.5% of individuals who did not RUI-marijuana who reported past-30 day marijuana use.

Factors associated with driving under the influence of marijuana (DUI-marijuana) and riding with a driver under the influence of marijuana (RUI-marijuana)

Our multivariable Poisson regression model (Table 6) with DUI-marijuana as the outcome included age, gender, race/ethnicity, frequent marijuana use and alcohol use (Table 6). In preliminary models, we found no association between education level and DUIM and dropped it from subsequent models. We found that Black, non-Hispanic individuals had an 81% lower risk of DUI-marijuana compared to White, non-Hispanics (RR=0.19; 95% CI:0.05-0.75). Frequent marijuana use (defined as using on 21 or more days in the past month) was associated with a 63% increased risk of DUI-marijuana compared to using on 20 days or fewer (RR=1.63; 95% CI:1.15-2.32). Of the model covariates, riding with a marijuana-using driver demonstrated the strongest association with DUI-marijuana. Individuals who rode with a driver under the influence of marijuana had more than triple the risk of DUI-marijuana compared to marijuana users who did not ride with a marijuana-using driver (RR=3.42; 95% CI: 2.28-5.15).

Table 5. Demographic and substance use characteristics by riding under the influence among MA adults

	Rode under the influence of marijuana			Did not ride under the influence of marijuana			Total respondents			
	n=187			n=2720			n=3022			
	%	95% LCI	95% UCI	%	95% LCI	95% UCI	%	95% LCI	95% UCI	P-value
Age										
18-20	12.2	3.7	20.8	2.8	1.3	4.3	3.9	2.2	5.6	<0.001
21-25	20.8	12.7	29.0	4.4	2.8	5.9	6.2	4.5	7.9	
26-29	15.5	7.6	23.4	8.1	6.2	10.0	9.0	7.1	10.9	
30-39	24.2	15.7	32.6	16.2	13.9	18.4	17.1	14.9	19.3	
40-49	11.5	5.5	17.6	18.1	15.7	20.5	17.4	15.1	19.6	
50=59	9.8	6.2	13.4	18.1	16.3	20.0	17.2	15.5	18.9	
60-69	4.6	2.2	6.9	16.7	15.0	18.4	15.3	13.8	16.8	
>=70	1.4	0.2	2.6	15.6	14.0	17.2	14.0	12.6	15.4	
Gender										
Female	55.1	45.1	65.1	52.4	49.5	55.2	52.7	49.9	55.4	0.599
Male	44.9	34.9	54.9	47.6	44.8	50.5	47.3	44.6	50.1	
Ethnicity										
Any Hispanic	15.2	7.2	23.1	8.6	6.4	10.7	9.3	7.2	11.4	0.389
White, non-Hispanic	67.5	57.4	77.6	75.1	72.3	78.0	74.3	71.5	77.0	
Black, non-Hispanic	7.8	1.0	14.7	5.7	4.1	7.2	5.9	4.3	7.5	
Asian, non-Hispanic	4.8	1.1	8.6	6.8	5.3	8.4	6.6	5.1	8.1	
Other, non-Hispanic	4.7	0.0	9.5	3.8	2.7	4.9	3.9	2.7	5.0	
Education										
High school or less	33.5	22.9	44.1	33.7	30.7	36.8	33.7	30.8	36.7	0.027
College	58.1	47.8	68.4	48.2	45.4	51.0	49.3	46.6	52.1	
Graduate school	8.3	4.6	12.1	18.1	16.4	19.7	16.9	15.4	18.5	
Used marijuana	70.6	61.9	79.3	15.5	13.2	17.8	21.7	19.2	24.3	<0.001
Drove under influence of marijuana	44.2	34.2	54.1	2.7	1.6	3.8	7.4	5.7	9.1	<0.001
Frequency of RUIM										
0 times	**-**	-	-	-	-	-	88.7	86.6	90.8	
once	26.5	18.2	34.8	-	-	-	3.0	2.0	4.0	
2-3 times	43.9	33.7	54.0	-	-	-	5.0	3.4	6.5	
4-5 times	10.5	4.9	16.1	-	-	-	1.2	0.5	1.8	
6 or more	19.2	11.9	26.5	-	-	-	2.2	1.3	3.0	

Drove under the influence of alcohol	18.1	10.7	25.5	5.5	4.1	6.8	6.9	5.4	8.4	0.001
Rode with driver under influence of alcohol	25.2	17.0	33.4	5.4	4.4	6.5	7.7	6.3	9.0	<0.001

Note: Table displays column percentages.

Table 6. Adjusted relative risk for driving under the influence of marijuana

	Adjusted Relative Risk	**95% Confidence Limits**		**P-value**
Age 25 and older (ref: 18-24 years)	1.02	0.72	1.43	0.911
Male (ref: Female)	1.32	0.96	1.82	0.089
Hispanic (ref: White, non-Hispanic)	1.22	0.76	1.97	0.404
Black (ref: White, non-Hispanic)	**0.19**	**0.05**	**0.75**	**0.018**
Asian (ref: White, non-Hispanic)	1.10	0.53	2.26	0.797
Other (ref: White, non-Hispanic)	1.30	0.60	2.83	0.507
≥21 days of marijuana use (Ref: ≤20 days)	**1.63**	**1.15**	**2.32**	**0.007**
Used alcohol	1.35	0.80	2.28	0.256
Rode with driver under influence of marijuana	**3.42**	**2.28**	**5.15**	**<.0001**

Note: Results from multivariable, modified Poisson regression. Only marijuana users included. All substance use and DUI or RUI variables refer to behavior in the past 30 days

Our multivariable Poisson regression model with RUI-marijuana as the outcome included age, gender, education, race/ethnicity, frequent marijuana use, alcohol use, and riding as a passenger with driver under the influence of alcohol (RUI-alcohol) (Table 7). We found that being age 25 years or older was associated with a nearly 50% reduction in the risk of RUI-marijuana, controlling for other factors. Using marijuana between 1-20 days per month was associated with having more than 5 times the risk of RUI-marijuana (RR=5.79; 95% CI: 3.70-9.07) compared to not using at all; using 21 or more days per month increased the risk more than 8 times (RR=8.57; 95% CI: 5.42-13.55). Riding with a driver who used alcohol was associated with more than twice the risk of riding with a marijuana using driver.

Table 7. Adjusted relative risk for riding as a passenger with a driver under the influence of marijuana

	Adjusted Relative Risk	95% Confidence Limits		P-value
Age 25 and older (ref: 18-24 years)	**0.52**	**0.37**	**0.74**	**<.0001**
Male (ref: Female)	0.76	0.55	1.05	0.098
College education (ref: ≤ High School)	1.04	0.69	1.56	0.865
Graduate education (ref: ≤ High School)	0.82	0.47	1.43	0.49
Hispanic (ref: White, non-Hispanic)	1.26	0.73	2.15	0.409
Black (ref: White, non-Hispanic)	1.24	0.65	2.39	0.512
Asian (ref: White, non-Hispanic)	1.35	0.63	2.90	0.441
Other (ref: White, non-Hispanic)	0.87	0.38	1.99	0.735
1 - 20 days of marijuana use (Ref: 0 days)	**5.79**	**3.70**	**9.07**	**<.0001**
≥21 days of marijuana use (Ref: 0 days)	**8.57**	**5.42**	**13.55**	**<.0001**
Used alcohol	0.97	0.62	1.53	0.907
Rode with a driver under influence of alcohol	**2.25**	**1.66**	**3.05**	**<.0001**

Note: Results from multivariable, modified Poisson regression. Entire sample (marijuana users and non-users) included. All substance use and DUI or RUI variables refer to behavior in the past 30 days

Fatality Analysis Reporting System (FARS)

From 2006-2016, there were an average of 373 traffic fatalities per year. 2015 had the lowest number of traffic deaths since 2009, 345, but in 2016 this number increased to 389, the highest number since 2007 when there were 434 traffic-related fatalities (Figure 1, Table 8).

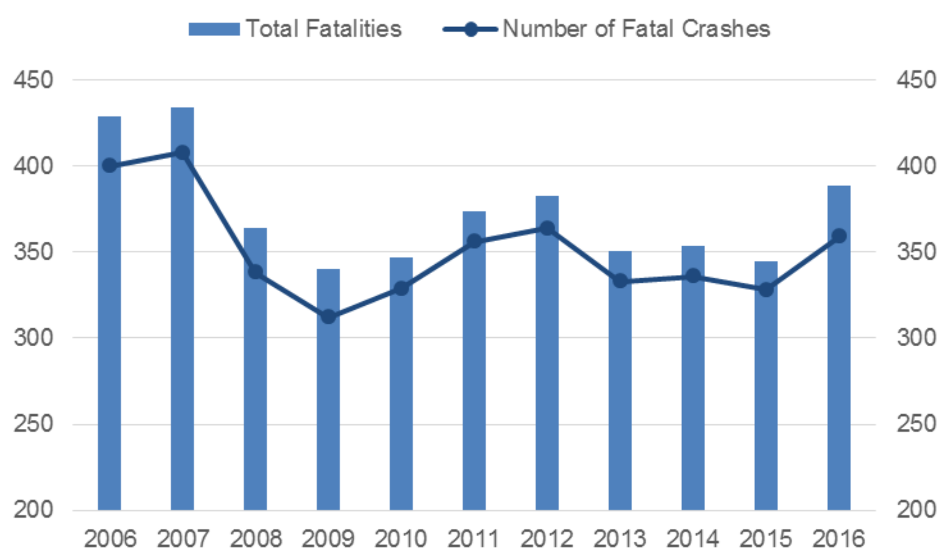


Figure 1. Total fatalities and number of motor vehicle crashes with a fatality in Massachusetts by year (2006-2016)

Table 8. Number of fatal crashes and total number of fatalities in Massachusetts, 2006-2016

Year	Number of Fatal Crashes	Traffic Fatalities in MA	Number of Drivers Involved in a Fatal Crash	Number of Deceased Drivers
2006	403	429	568	284
2007	408	434	570	277
2008	338	364	442	218
2009	313	340	447	216
2010	330	347	448	220
2011	356	374	499	239
2012	365	383	497	225
2013	334	351	445	212
2014	336	354	456	212
2015	328	345	457	210
2016	359	389	501	234

The number of drivers involved in a fatal crash followed a similar trend to the number of fatalities per year (Table 8, Figure 2.) Overall, there were an average of 484 drivers involved in a fatal crash each year from 2006 to 2016 and an average of 231 drivers were deceased from motor vehicle crashes.

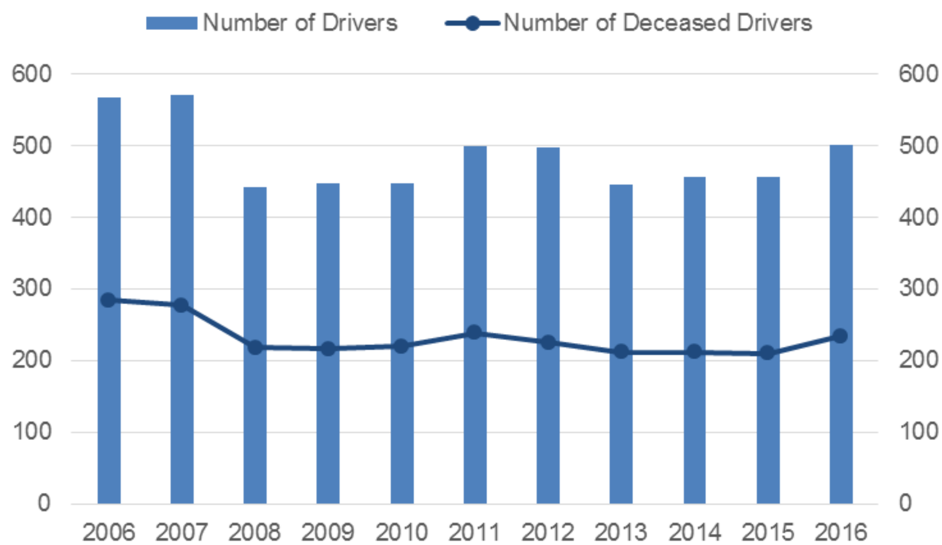


Figure 2. Number of drivers involved in fatal crashes and number of deceased drivers in MA by year (2006-2016)

Toxicological Testing

When drivers in a fatal crash are given a blood test, it is indicated in FARS under the ATST_TYP (alcohol test type) and DRUGTST (drug test type) fields. There were three instances in the 11-year sample where a driver was given a blood test for drugs but not for alcohol, and 54 instances of the reverse, when a driver's blood was tested for alcohol but not drugs. Nearly 1900 drivers had their blood tested for both drugs and alcohol after a fatal crash in the 11-year sample, out of 5330 total crash-involved drivers, which is approximately 36% (Table 9.).

Table 9. Blood test types for drivers involved in fatal crashes in MA (2006-2016)

Year	Alcohol Test Only	Drug Test Only	Alcohol and Drug Test	Total Drivers	Percent tested for alcohol and drugs
2006	3	1	215	568	37.9
2007	9	0	207	570	36.3
2008	16	0	156	442	35.3
2009	9	0	155	447	34.7
2010	2	0	186	448	41.5
2011	3	1	149	499	29.9
2012	1	0	172	497	34.6
2013	1	0	164	445	36.9
2014	4	0	142	456	31.1
2015	6	0	159	457	34.8
2016	0	1	192	501	38.3
Total	**54**	**3**	**1897**	**5330**	**35.6**

Within the FARS database there are three options that can be selected to indicate that a person was tested for the presence of drugs: (1) blood test, (2) urine test, and (3) both blood and urine tests. Among these three options, for both surviving and deceased drivers, blood tests were used, almost exclusively, to determine the presence of drugs. In the 11-year sample, 1897 drivers were given only a blood test, three were given a urine test only and only one person was given both a blood and urine test to determine if drugs were present in their system after being involved in a fatal crash.

Overall, approximately 73% of the drivers who were deceased in a crash were given a post-mortem blood test for alcohol or drugs. By contrast, less than 1% of drivers who survived a crash in which there was at least one fatality were given a blood test for alcohol or drugs according to the FARS data (Figure 3). During the 11-year study period (2006-2016), the highest proportion of deceased drivers given a blood test for alcohol or drugs was 83% in 2010 and the lowest was 63% in 2011. The highest proportion of surviving drivers given a blood test for alcohol or drugs was 2% in 2005 and the lowest was 0% in 2009 and 2015. In 2016, the proportion of deceased drivers given a blood test for alcohol or drugs was 82%, which was a slightly higher testing rate for deceased drivers than in the preceding five years, and less than 1% of surviving drivers were tested.

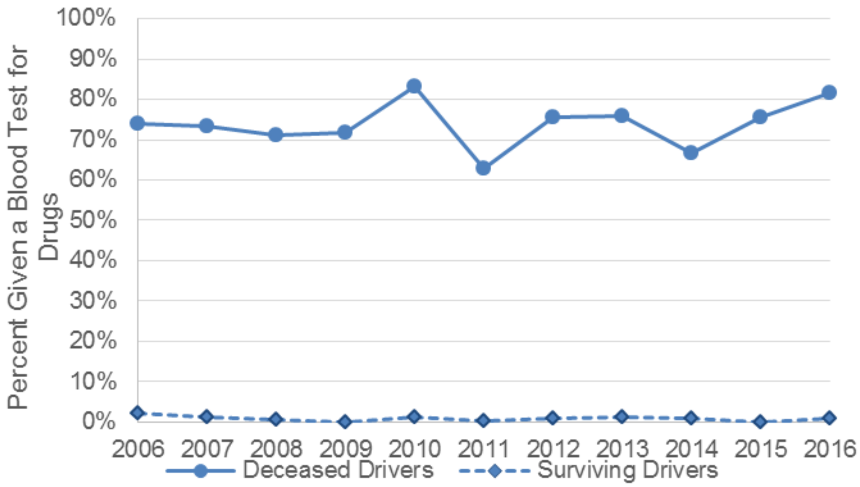


Figure 3. Percentage of deceased and surviving drivers in fatal crashes given a Blood test for drugs

To detect potential demographic differences in blood-testing trends, testing rates were examined by race/ethnicity. Figure 4 displays the percent of all deceased drivers who were given a blood test by race/ethnicity. The “Other, non-Hispanic” category was lower than others, due to this category containing the “Unknown” race option which was strongly correlated with having an “unknown drug test type.

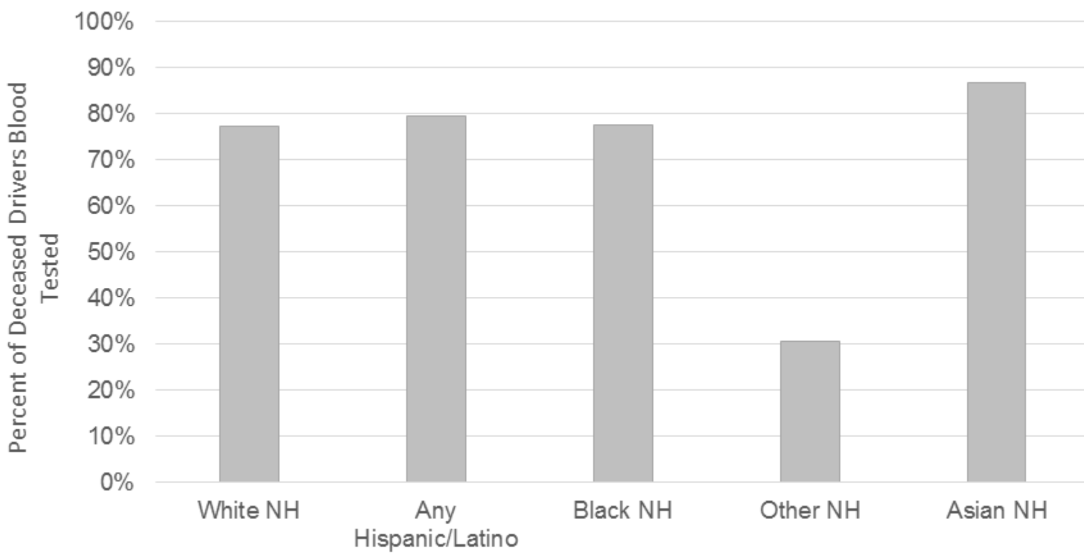


Figure 4. Percent of deceased drivers given a blood test for drugs, by race/ethnicity.

Marijuana Use

The prevalence of marijuana use among deceased drivers blood-tested for drugs was evaluated by examining how often they tested positive for any cannabinoid (Figure 5).

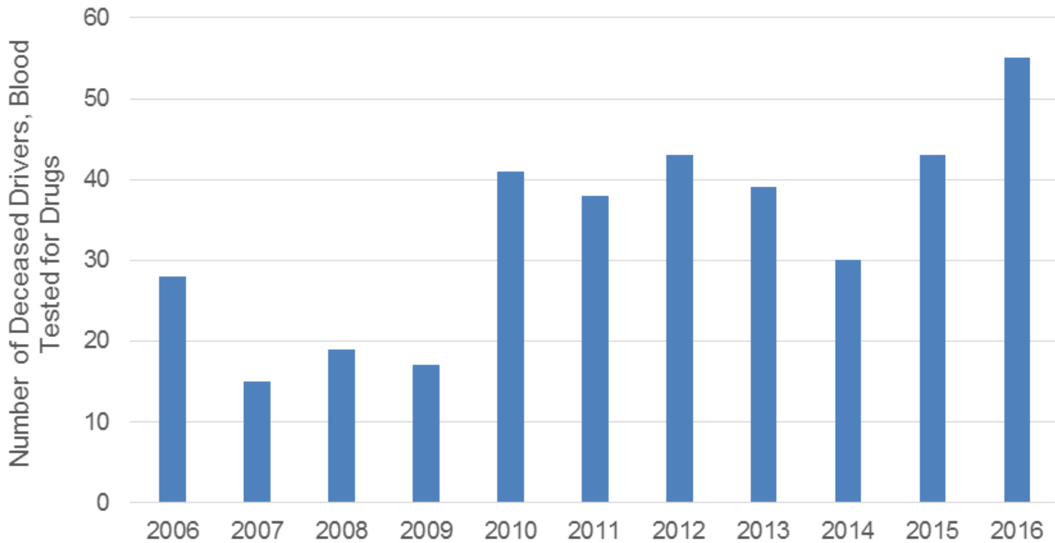


Figure 5. Number of deceased drivers given a blood test for drugs testing positive for any cannabinoid

When examining the frequency in which deceased drivers given a blood test for drugs tested positive for any cannabinoid, a noticeable increase was observed in 2010 (Figure 6).

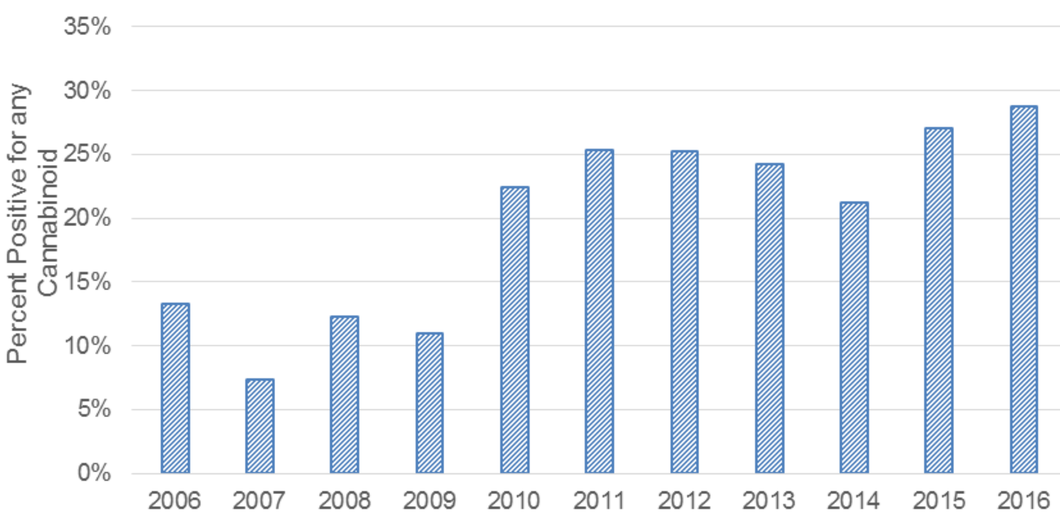


Figure 6. Percentage of deceased drivers given a blood test for drugs who tested positive for any cannabinoid

The data was further examined by driver sex, race, and age in order to identify potential differences in marijuana use in these demographic groups (Table 10).

Table 10. Number of deceased drivers given a blood test for drugs who tested positive for any cannabinoid by sex, race, and age

Demographic Category	Any Cannabinoid		No Cannabinoids		Total
	n	%	n	%	
Male	297	20.3%	1167	79.7%	1464
Female	71	17.1%	343	82.9%	414
White, non-Hispanic	275	17.8%	1272	82.2%	1547
Black, non-Hispanic	42	34.4%	80	65.6%	122
Asian, non-Hispanic	1	7.7%	12	92.3%	13
Other, non-Hispanic	12	18.8%	52	81.3%	64
Any Hispanic/Latino	38	28.8%	94	71.2%	132
<18 years	12	26.1%	34	73.9%	46
18-20 years	47	32.9%	96	67.1%	143
21-25 years	115	33.0%	233	67.0%	348
26-34 years	87	27.4%	231	72.6%	318
35-64 years	99	13.3%	644	86.7%	743
65+ years	8	2.9%	272	97.1%	280

Note: Rows percentages are reported. Any cannabinoid + no cannabinoid will sum to 100% within demographic groups.

When examining cannabinoid presence, there was no statistically significant difference between male and female drivers (Figure 7).

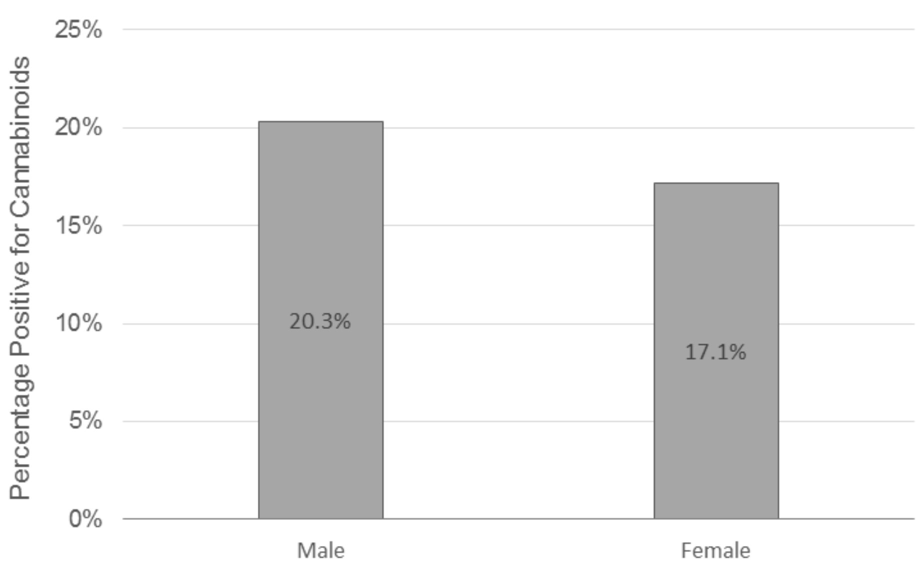


Figure 7. Percentage of deceased drivers given a blood test for drugs who tested positive for any cannabinoid, by driver sex

When examining race/ethnicity of deceased drivers given a blood test for drugs, the proportion of individuals of any Hispanic/Latino ethnicity and Black, non-Hispanic race/ethnicity who tested positive for cannabinoids was higher than for White, non-Hispanic drivers (Figure 8). There were very small samples of deceased Asian, non-Hispanic and Other, non-Hispanic drivers.

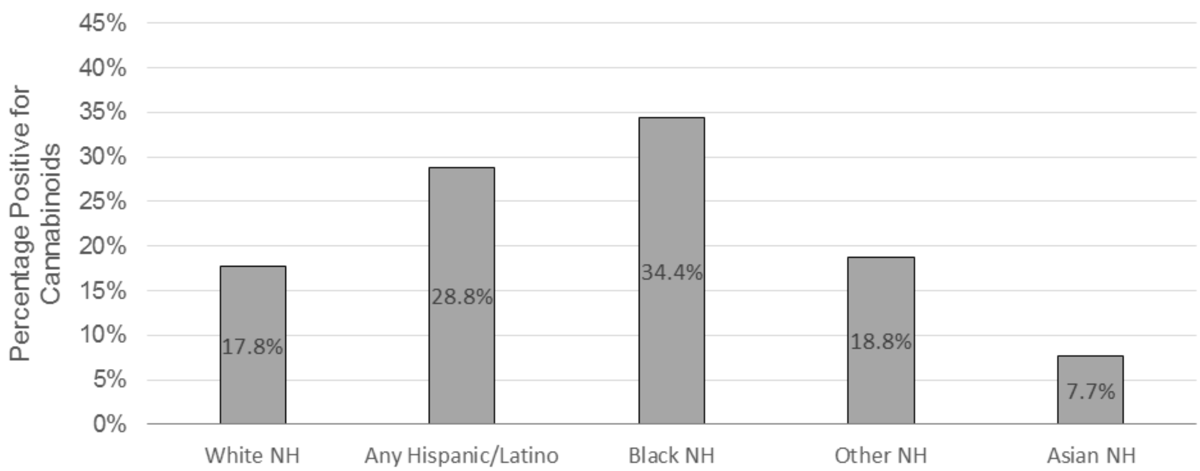


Figure 8. Percentage of all deceased drivers given a blood test for drugs who tested positive for any cannabinoid, by driver race/ethnicity

Figure note: NH=non-Hispanic

The presence of any cannabinoid in deceased drivers given a blood test for drugs was most common in young drivers and decreased precipitously from the 26-34 age group to the 35-64 age group, as shown in Figure 9.

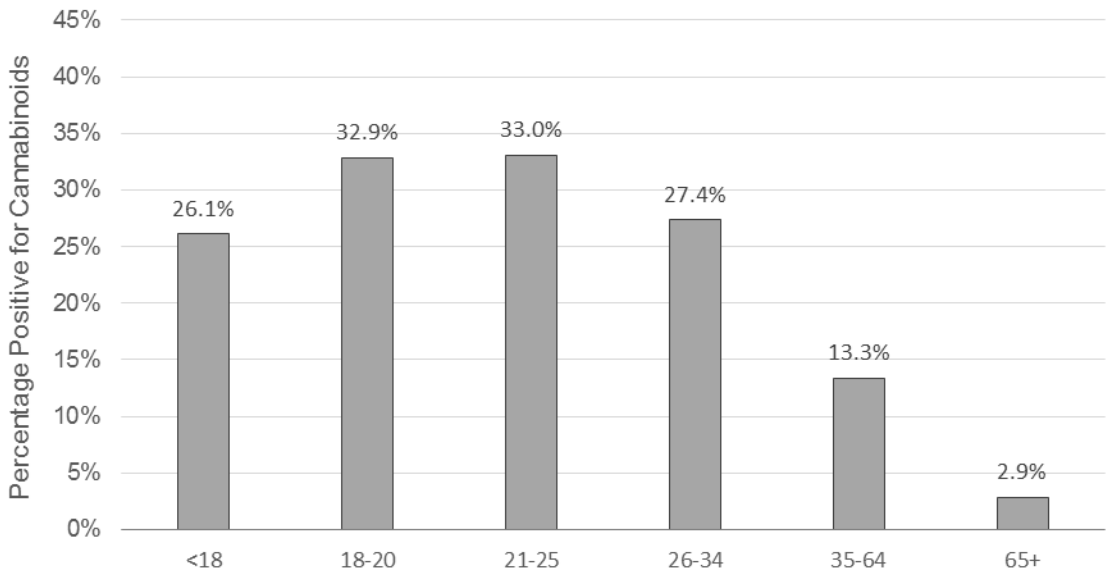


Figure 9. Percentage of deceased drivers given a blood for drugs who tested positive for any cannabinoid by driver age

Alcohol and Drug Use

Reducing the prevalence of drunk driving has long been a focal point for the public health community as a way to reduce motor vehicle crash injuries and deaths. As such, the presence of alcohol in fatal crashes was examined, both by itself and in conjunction with the presence of cannabinoids (Table 11). For all demographic categories, with the exception of Black, non-Hispanics there were more blood-tested, deceased drivers with a blood alcohol content greater than or equal to 0.08% than with cannabinoids in their system.

Cannabinoid results were examined in conjunction with alcohol use. Table 11 displays the number of deceased drivers given a blood test for drugs and alcohol who tested positive for any cannabinoid only, had a BAC ≥ 0.08% only, had both a positive cannabinoid result and a BAC ≥ 0.08% or tested negative for cannabinoids and had a BAC less than 0.08%.

Table 11. Number of deceased drivers given a blood test for alcohol and drugs who tested positive for any cannabinoid and/or had a blood alcohol content (BAC) ≥ 0.08% by sex, race/ethnicity, and age.

Demographic Category	Any Cannabinoid, BAC ≤ 0.08%		No Cannabinoid, BAC ≥ 0.08%		Any Cannabinoid + BAC≥ 0.08%		No Cannabinoid, BAC ≤ 0.08%		Total
	n	%	n	%	n	%	n	%	
Male	176	12.0%	383	26.2%	119	8.1%	752	51.4%	1464
Female	33	8.0%	86	20.8%	38	9.2%	245	59.2%	414
White, non-Hispanic	151	9.8%	395	25.5%	124	8.0%	840	54.3%	1547
Any Hispanic/Latino	29	22.0%	33	25.0%	9	6.8%	57	43.2%	132
Black, non-Hispanic	21	17.2%	21	17.2%	19	15.6%	57	46.7%	122
Other, non-Hispanic	8	12.5%	17	26.6%	4	6.3%	34	53.1%	64
Asian, non-Hispanic	0	0.0%	3	23.1%	1	7.7%	9	69.2%	13
<18 years	8	17.4%	7	15.2%	4	8.7%	26	56.5%	46
18-20 years	29	20.3%	31	21.7%	17	11.9%	62	43.4%	143
21-25 years	61	17.5%	103	29.6%	54	15.5%	126	36.2%	348
26-34 years	46	14.5%	104	32.7%	40	12.6%	119	37.4%	318
35-64 years	59	7.9%	206	27.7%	40	5.4%	418	56.3%	743
65+ years	6	2.1%	18	6.4%	2	0.7%	246	87.9%	280

Table Note: Other drugs could be present in any column. A small portion (2.4%) of all deceased drivers given a blood test for alcohol and drugs had an unknown alcohol result and are excluded from the table.

When examining alcohol and cannabis presence in fatal crash-involved drivers by age group, a trend emerges. The proportion of drivers that had only a BAC ≥ 0.08% increased with age until peaking in the 26-34 years age category, whereas those with only a positive cannabinoid result peaked in the 18-20 years age group and then declined with age (Figure 10). As expected from these two trends, having both a positive cannabinoid result and a BAC ≥ 0.08% peaked in the 21-25 years age group.

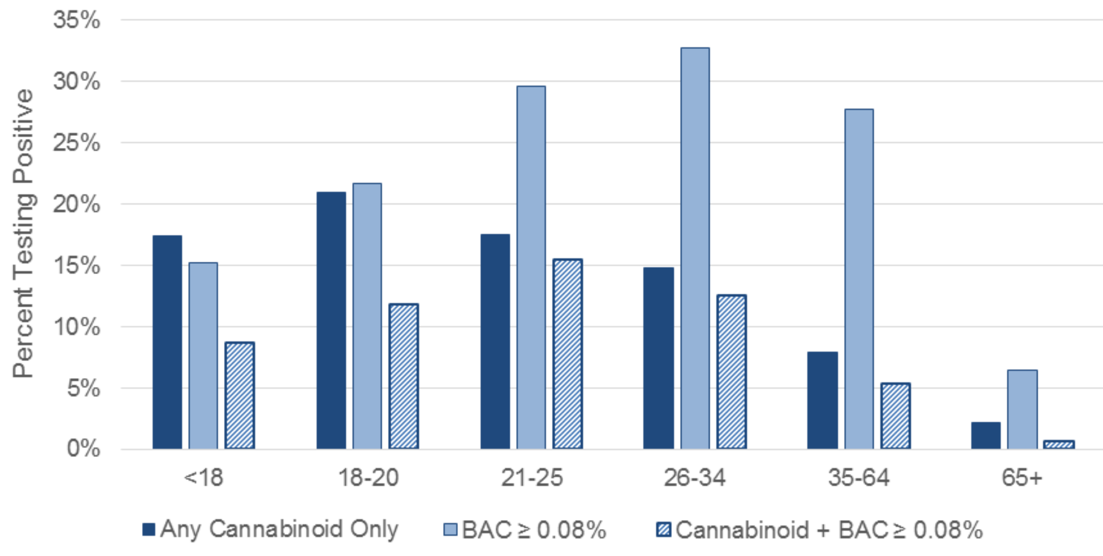


Figure 10. Percentage of all deceased drivers given a blood test for alcohol and drugs who tested positive for any cannabinoid and/or had a blood alcohol content (BAC) ≥ 0.08%, by driver age (years).

The trend in drivers with a BAC ≥ 0.08% and/or positive cannabinoid results was examined over time (Figure 11.) In 2007 and 2008, nearly 40% of all deceased drivers given a blood test for alcohol and drugs had a BAC ≥ 0.08%.

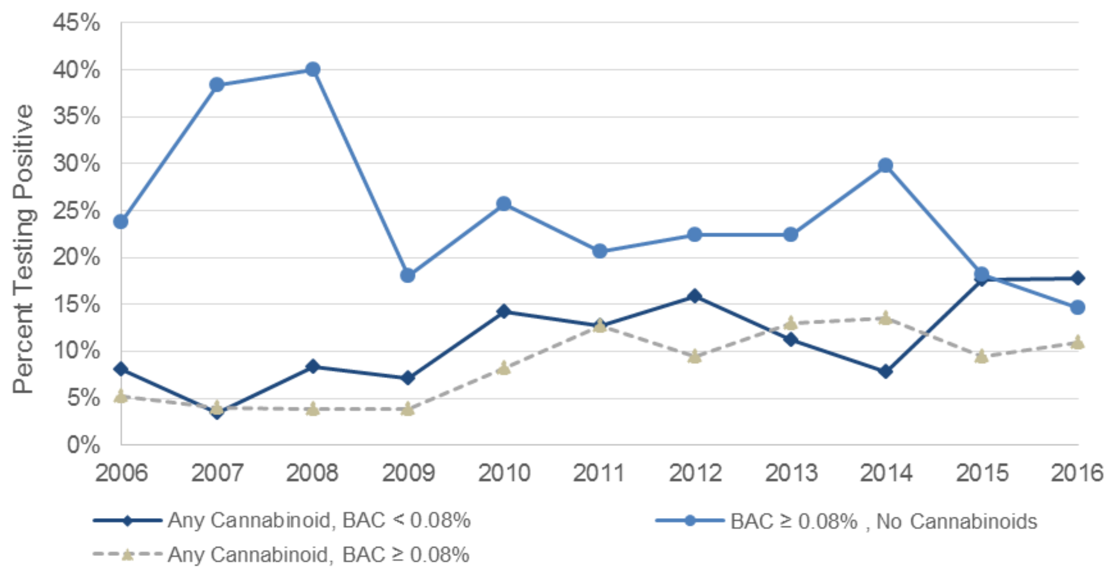


Figure 11. Percentage of all deceased drivers given a blood test for alcohol and drugs who tested positive for any cannabinoid and/or had a BAC >= 0.08% in Massachusetts from 2006 to 2016

The number of deaths resulting from these crashes has followed a similar trend (Figure 12). While the number of deaths from drivers with a BAC ≥ 0.08% and no cannabinoids in their blood has steadily decreased since 2006, the number of deaths from drivers with cannabinoids and with a BAC below the legal limit of 0.08%, has steadily increased.

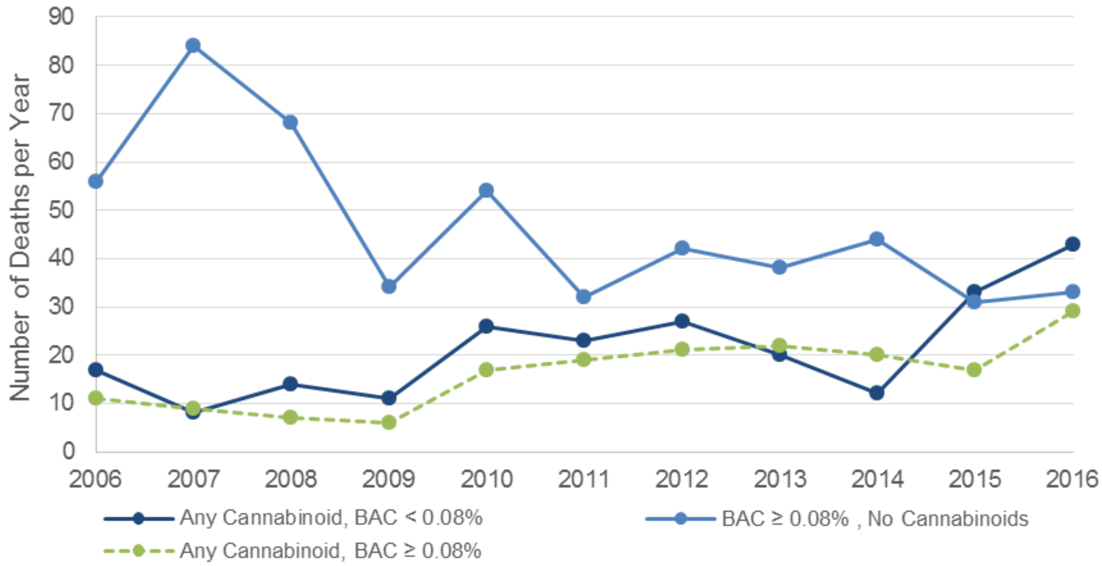


Figure 12. Number of deaths per year resulting from crashes with deceased drivers given a blood test for alcohol and drugs who tested positive for any cannabinoid and/or had a BAC ≥ 0.08% in Massachusetts from 2006 to 2016.

The presence of other drugs was examined in addition to alcohol and cannabinoids. Figure 13 shows the frequency at which other drugs were present in blood-tested, deceased drivers. The drug categories were taken from the 2016 FARS/NASS GES Coding and Validation Manual (National Highway Traffic Safety Administration, 2016) with “Other” encompassing all drugs other than cannabinoids, narcotics, stimulants, depressants, and hallucinogens/PCP. Overall, all drug categories have generally trended upwards in the past 11 years.

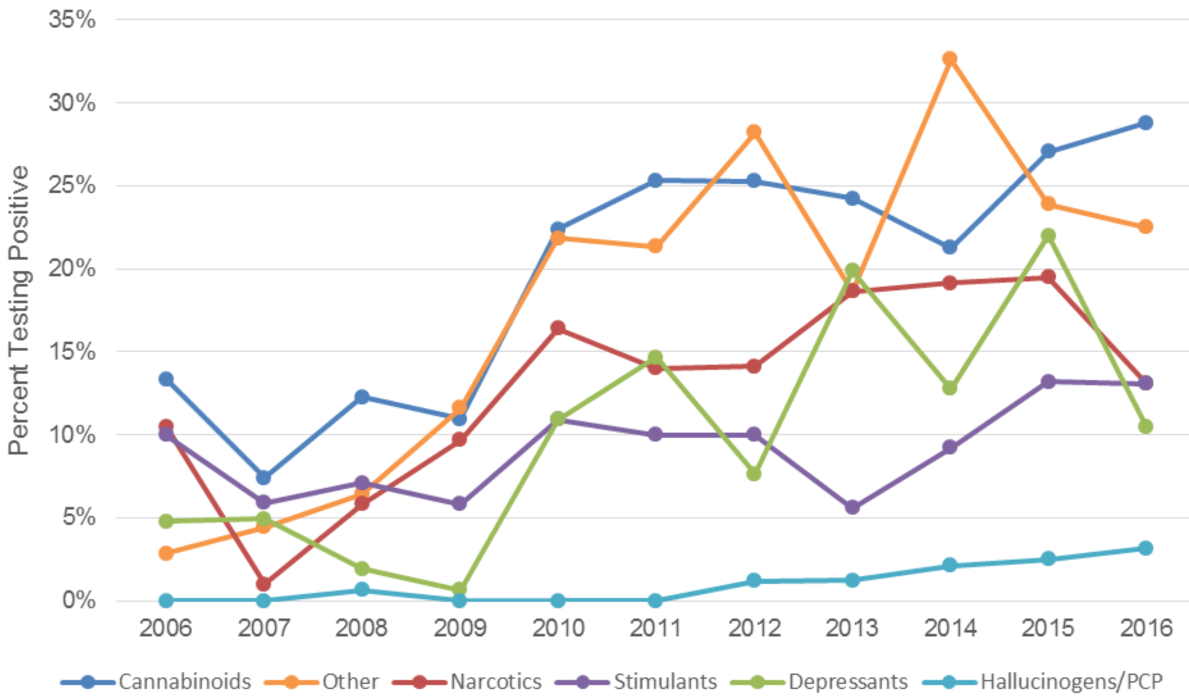


Figure 13. Percentage of all deceased, drivers given a blood test for drugs who tested positive for various drug categories in Massachusetts from 2006 to 2016.

Figure note: Totals will not sum to 100% as drivers could test positive in multiple categories. Cases with a positive test result but unknown drug type are excluded (0.2% of drivers given a blood test for drugs).

Drugs besides cannabinoids were analyzed in conjunction with alcohol (BAC ≥ 0.08) and any cannabinoids (Table 12). When examining racial/ethnic differences, White, non-Hispanic drivers were more likely to have only other drugs in their system than cannabinoids (Table 13). The same did not hold true for drivers with any Hispanic/Latino ethnicity and Black, non-Hispanic drivers. Those groups were equally or more likely to have cannabinoids only in their system than other drugs only. Sample sizes were too small for the other racial/ethnic categories to make similar comparisons.

Table 12, Table 13 and Table 14 show the number and frequency of deceased drivers by sex, race and age (respectively) testing positive for the seven combinations of cannabinoids, drugs and alcohol (defined as a BAC ≥ 0.08%) or none of those results.. Females were less likely than males to have a blood alcohol content above the legal limit or test positive for cannabinoids only, but were more likely than males to have a positive result for only other drugs (Table 12).

Table 12. Number and proportion of deceased drivers given a blood test for drugs who tested positive for any cannabinoid and/or had a blood alcohol content (BAC) ≥ 0.08% and/or positive results for other drugs, by driver sex

Type	Male		Female	
	n	%	n	%
Cannabinoids Only (MJ)	98	6.7%	12	2.9%
BAC ≥ 0.08%	270	18.4%	53	12.8%
Other Drugs Only (Drugs)	261	17.8%	110	26.6%
MJ + BAC ≥ 0.08%	65	4.4%	23	5.6%
MJ + Drugs	80	5.5%	21	5.1%
BAC ≥ 0.08% + Drugs	113	7.7%	33	8.0%
MJ + BAC ≥ 0.08% + Drugs	54	3.7%	15	3.6%
None	523	35.7%	147	35.5%
Total	**1464**	**100%**	**414**	**100%**

Table 13. Number of deceased drivers given a blood test who tested positive for any cannabinoid and/or a BAC >= 0.08 and/or other drugs by driver race/ethnicity

Type	White NH		Hispanic/ Latino		Black NH		Other NH		Asian NH	
	n	%	n	%	n	%	n	%	n	%
Cannabinoids Only (MJ)	73	4.7%	17	12.9%	17	13.9%	3	4.7%	0	0.0%
BAC ≥ 0.08%	267	17.3%	27	20.5%	15	12.3%	12	18.8%	2	15.4%
Other Drugs Only (Drugs)	333	21.5%	10	7.6%	16	13.1%	11	17.2%	1	7.7%
MJ + BAC ≥ 0.08%	71	4.6%	4	3.0%	11	9.0%	2	3.1%	0	0.0%
MJ + Drugs	78	5.0%	12	9.1%	6	4.9%	5	7.8%	0	0.0%
BAC ≥ 0.08% + Drugs	128	8.3%	6	4.5%	6	4.9%	5	7.8%	1	7.7%
MJ + BAC ≥ 0.08% + Drugs	53	3.4%	5	3.8%	8	6.6%	2	3.1%	1	7.7%
None	544	35.2%	51	38.6%	43	35.2%	24	37.5%	8	61.5%

Table Note: NH= Non-Hispanic

Examining results for alcohol, marijuana, and other drugs by age, the percentage of deceased drivers within an age group testing positive for other drugs increases with age and is highest for the 65+ age bracket (Tables 14a and 14b). Deceased blood-tested drivers in this age range rarely tested positive for cannabinoids or had a BAC above 0.08%, but frequently tested positive for other drugs (Table 14b). This is likely due to the number of medications taken by older individuals that are reported in FARS drug results.

Table 14a and 14b. Number and proportion of deceased drivers given a blood test Testing Positive for Any Cannabinoid and/or a blood alcohol content (BAC) >= 0.08 and/or other drugs by driver age

Type	**<18**		**18-20**		**21-25**	
	n	**%**	**n**	**%**	**n**	**%**
Cannabinoids Only (MJ)	7	15.2%	17	11.9%	31	8.9%
BAC ≥ 0.08% Only	6	13.0%	24	16.8%	79	22.7%
Other Drugs Only (Drugs)	6	13.0%	13	9.1%	36	10.3%
MJ + BAC ≥ 0.08%	3	6.5%	11	7.7%	29	8.3%
MJ + Drugs	1	2.2%	13	9.1%	30	8.6%
BAC ≥ 0.08% + Drugs	1	2.2%	7	4.9%	24	6.9%
MJ + BAC ≥ 0.08% + Drugs	1	2.2%	6	4.2%	25	7.2%
None	21	45.7%	52	36.4%	94	27.0%
Total	**46**	**100%**	**143**	**100%**	**348**	**100%**

Type	**26-34**		**35-64**		**65+**	
	n	**%**	**n**	**%**	**n**	**%**
Cannabinoids Only (MJ)	24	7.5%	30	4.0%	1	0.4%
BAC ≥ 0.08% Only	76	23.9%	127	17.1%	11	3.9%
Other Drugs Only (Drugs)	47	14.8%	174	23.4%	95	33.9%
MJ + BAC ≥ 0.08%	20	6.3%	24	3.2%	1	0.4%
MJ + Drugs	23	7.2%	29	3.9%	5	1.8%
BAC ≥ 0.08% + Drugs	28	8.8%	79	10.6%	7	2.5%
MJ + BAC ≥ 0.08% + Drugs	20	6.3%	16	2.2%	1	0.4%
None	80	25.2%	264	35.5%	159	56.8%
Total	**318**	**100%**	**743**	**100%**	**280**	**100%**

Crash Data System (CDS)

The results from our query of non-fatal crash data to identify officer-written crash narratives which contained the words “marijuana”, “weed”, and “cannabis” are shown in Figure 14. This figure displays the number of non-fatal crashes per year with a crash narrative containing one or more of these keywords. Data from 2017 was included because it was available from CDS. The number of crashes per year where the responding officer suspected marijuana-involvement has followed the same increasing trend as has fatal crashes (Figure 14).

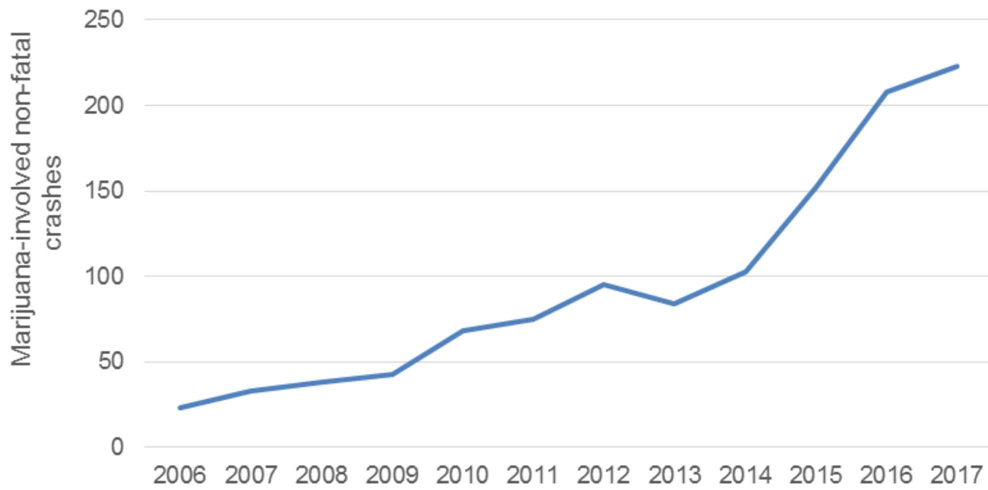


Figure 14. Non-fatal motor vehicle crashes which contain a crash narrative containing the keywords "marijuana", "weed", and/or "cannabis," by year

Discussion

In 2017, 7.2% of Massachusetts adults drove under the influence of marijuana (DUI) and 11.7% rode with a driver who was under the influence of marijuana (RUI). Among marijuana users, nearly 4 in 10 reported DUI and or RUI-marijuana. When stratified by age, younger age groups appeared more likely to engage in both behaviors. We found that DUI-marijuana was reported by 25.6% of individuals age 18-20 years and 24.1% of those age 21-24 years. RUI-marijuana was reported by 36% of those age 18-20 years and 38% of those age 21-25 years. Prevalence was much lower for both DUI-marijuana and RUI-marijuana among adults age 25 years and older compared to those age 24 years and younger.

Compared to estimates from other states, the prevalence in Massachusetts of DUI- and RUI-marijuana appear higher, especially when stratified by age. However, some aspects of our results are consistent with prior work. For example, prior estimates from Colorado published in 2016 show that 6% of young adults age 18-25 years reported driving after using marijuana, while 4.8% 26-34 years old reported the behavior. Thus, our point estimates among Massachusetts adults are more than four times higher than estimates from Colorado (Department of Health and Environment). The results across states, however, are consistent in finding that prevalence of DUI-marijuana among older age groups is lower compared to younger age groups. Cross-state differences in results may be due to several factors, including regional beliefs, attitudes and policies related to DUI-marijuana.

Some prior studies have found that males are over-represented among those who drive under the influence of marijuana (Arria, Caldeira, Vincent, Garnier-Dykstra, & O'Grady, 2011; Whitehill et al., 2014). In the present study, this was not the case, with females representing about 42% of marijuana users, and a similar proportion of those who DUI-marijuana.

About 4 out of 10 Massachusetts adults who drove under the influence of marijuana reported driving under the influence of alcohol and marijuana, simultaneously. This is concerning, since studies suggest that the crash risk from the combination of alcohol and marijuana may be higher than the risk from using either substance alone (Chihuri, Li, & Chen, 2017). Monitoring and preventing driving under the combination of alcohol and marijuana is an important consideration as legalization is implemented.

The analysis of data from fatal crashes in Massachusetts demonstrated that there were approximately 360 crashes in 2016 in which at least one person died, with a total of nearly 390 fatalities, of which 234 were drivers. Many of these crashes are preventable and reducing potentially-impairing alcohol and drug use by drivers should remain a priority as marijuana policies are changing within the state. Among the fatal crashes, approximately 36% of drivers received a blood drug test between 2002-2016. This included testing 73% of fatally injured drivers, and less than 1% of surviving drivers. To contextualize these numbers, prior studies seeking to establish national or cross-state comparisons using FARS data only include states in which testing rates are above 80% for deceased drivers. Thus, comparisons to other states may not be appropriate due to lower-than-ideal testing rates in Massachusetts.

We observed a trend that may indicate an increasing proportion of decreased drivers involved in fatal motor vehicle crashes testing positive for cannabinoids. This does not mean the drivers were impaired by marijuana at the time of the crash, and could merely indicate increasing population-level marijuana use, which would be consistent with the results from the adult survey. The analysis of FARS data showed a decrease over time in the number of deaths per year resulting from crashes with drivers who had a blood alcohol content above 0.08%, but an increase in the number of deaths with drivers testing positive for cannabinoids or a blood alcohol content above 0.08% plus cannabinoids. This trend is something that warrants future investigation in alternate data sources with regard to the possibility of either substitution (i.e. drivers using marijuana instead of alcohol) or combination (e.g. drivers using alcohol and marijuana) effects.

Limitations

As with all studies, these data are subject to several limitations. As reported in Task 1, Chapter 2, the survey response rate was 21.7%. Although this rate is in line with surveys of this kind, there is a possibility for response bias on a measure not accounted for by the weighting, which would impact generalizability. For example, if adults who did not use marijuana discarded the survey but those who used marijuana were more likely to return it, this could lead to overestimation of the prevalence of marijuana use, and related measures like driving under the influence. As marijuana legalization continues to be implemented in the Commonwealth, it will be important to replicate this survey as well as expand data collection to additional modalities that will provide a robust picture of marijuana use and related behaviors.

The cross-sectional survey design precludes determining the temporal sequencing of experiences and prevents drawing of causal inferences. Marijuana and other substance use were both self-reported, and not corroborated by testing of biological samples. Social desirability bias can lead to underestimates in survey research, however a unique contribution of this study is that it is the first to be conducted in Massachusetts after legalization of marijuana for adult recreational use. Data was collected in late 2017, nearly one year after marijuana became legal for recreational use by adults, and several years after legalization of medical marijuana in Massachusetts. This should reduce potential for social desirability bias that leads to under-reporting of marijuana use. Illegal behaviors (e.g. use of illicit drugs; driving under the influence of alcohol or drugs) may be underreported.

Small cell sizes for categories of some variables likely means that models including them are underpowered. For some variables, fewer than 5 respondents endorsed the items. Weighted estimates based on these few data should be interpreted carefully.

In conclusion, this study presents the first estimate of prevalence of DUI-marijuana and RUI-marijuana among Massachusetts adults after the legalization of marijuana for use by all adults over 21 years. Driving under the influence of marijuana is common among marijuana users, particularly among young adults. Riding as a passenger with a marijuana-using driver is even more common. Efforts to address social norms about driving under the influence of marijuana is one strategy that may reduce this behavior. In the meantime, more research to understand the true crash risk and methods for deterring impaired driving are needed.

Analysis of fatality data is also subject to limitations. In addition to a lower-than-ideal rate of testing, described above, prior studies have questioned the validity of drug data in FARS due to variability in drug testing practices, even within states (Berning & Smither, 2014). The data used for this study, which showed a dramatic dip to near-zero levels of recorded delta-9-THC results in 2011-2012 and precluded use of that data for this analysis likely reflects the type of testing and/or data coding problems that plague the FARS data.

References

Alcohol and Drug Abuse Institute. (2013). What is Cannabis? Retrieved from http://learnaboutmarijuanawa.org/factsheets/whatiscannabis.htm

Alere DDS®2 Mobile Test System: Rapid Screening for Drugs of Abuse in Oral Fluid. (2018). Retrieved from https://www.alere.com/en/home/product-details/dds2-mobile-test-system.html#

Allen, K. R. (2011). Screening for drugs of abuse: which matrix, oral fluid or urine? *Annals of Clinical Biochemistry, 48*(6), 531-541.

Arnett, J. J., & Tanner, J. L. (Eds.). (2004). *Emerging Adulthood: The Winding Road from the Late Teens through the Twenties*. New York, NY: Oxford University Press.

Arria, A. M., Caldeira, K. M., Vincent, K. B., Garnier-Dykstra, L. M., & O'Grady, K. E. (2011). Substance-related traffic-risk behaviors among college students. *Drug Alcohol Depend, 118*(2-3), 306-312. doi:10.1016/j.drugalcdep.2011.04.012

Asbridge, M., Hayden, J. A., & Cartwright, J. L. (2012). Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. *BMJ, 344*, e536.

Banta-Green, C., Rowhani-Rahbar, A., Ebel, B. E., Andris, L. M., & Qiu, Q. (2016). Cannabis Use among Drivers Suspected of Driving Under the Influence or Involved in Collisions: Analyses of Washington State Patrol Data.

Berning, A., & Smither, D. (2014). *Understanding the Limitations of Drug Test Information, Reporting, and Testing Practices in Fatal Crashes*. Retrieved from Washington, D.C.:

Blencowe, T., Pehrsson, A., & Lillsunde, P. (2010). *Analytical evaluation of oral fluid screening devices and preceding selection procedures*. Retrieved from https://www.bast.de/Druid/EN/deliverales-list/downloads/Deliverable_3_2_2.pdf?__blob=publicationFile&v=1

Bondallaz, P., Favrat, B., Chtioui, H., Fornari, E., Maeder, P., & Giroud, C. (2016). Cannabis and its effects on driving skills. *Forensic Science International, 268*, 92-102. doi:https://doi.org/10.1016/j.forsciint.2016.09.007

Bosker, W. M., & Huestis, M. A. (2009). Oral fluid testing for drugs of abuse. *Clinical chemistry, 55*(11), 1910-1931.

Chen, Q., Williams, S. Z., Liu, Y., Chihuri, S. T., & Li, G. (2018). Multiple imputation of missing marijuana data in the Fatality Analysis Reporting System using a Bayesian multilevel model. *Accid Anal Prev, 120*, 262-269. doi:10.1016/j.aap.2018.08.021

Chihuri, S., Li, G., & Chen, Q. (2017). Interaction of marijuana and alcohol on fatal motor vehicle crash risk: a case-control study. *Inj Epidemiol, 4*(1), 8. doi:10.1186/s40621-017-0105-z

Compton, R. (2017). *Marijuana-Impaired Driving A Report to Congress*. Retrieved from Washington, DC:

Davis, K. C., Allen, J., Duke, J., Nonnemaker, J., Bradfield, B., Farrelly, M. C., . . . Novak, S. (2016). Correlates of Marijuana Drugged Driving and Openness to Driving While High: Evidence from Colorado and Washington. *PLoS One, 11*(1), e0146853. doi:10.1371/journal.pone.0146853

Department of Health and Environment, C. Adult marijuana use trends. *Monitoring trends in adult marijuana use.*

Department of Health and Human Services. (2015). *Mandatory Guidelines for Federal Workplace Drug Testing Programs*. Retrieved from

Dräger DrugTest® 5000: Analysis system for detecting drugs. (2018). Retrieved from https://www.draeger.com/Library/Content/drugtest_5000_pi_9041006_en.pdf

Drummer, O. H. (2010). Forensic toxicology. *Exs, 100*, 579-603.

Edwards, L. D., Smith, K. L., & Savage, T. (2017). Drugged Driving in Wisconsin: Oral Fluid Versus Blood. *J Anal Toxicol, 41*(6), 523-529. doi:10.1093/jat/bkx051

Gentili, S., Solimini, R., Tittarelli, R., Mannocchi, G., & Busardo, F. P. (2016). A Study on the Reliability of an On-Site Oral Fluid Drug Test in a Recreational Context. *J Anal Methods Chem, 2016*, 1234581. doi:10.1155/2016/1234581

Gentili, S., Solimini, R., Tittarelli, R., Mannocchi, G., & Busardò, F. P. (2016). A Study on the Reliability of an On-Site Oral Fluid Drug Test in a Recreational Context. *J Anal Methods Chem, 2016*, 1234581. doi:10.1155/2016/1234581

Goodwin, R. S., Darwin, W. D., Chiang, C. N., Shih, M., Li, S.-H., & Huestis, M. A. (2008). Urinary elimination of 11-nor-9-carboxy-delta9-tetrahydrocannabinol in cannabis users during continuously monitored abstinence. *Journal of analytical toxicology, 32*(8), 562-569.

Grondel, D., Hoff, S., & Doane, D. (2018). *Marijuana use, Alcohol Use, and riving in Washington State: Emerging Issues with Poly-Drug Use on Washington Roadways*. Retrieved from http://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2018/05/Marijuana-and-Alcohol-Involvement-in-Fatal-Crashes-in-WA_FINAL.pdf

Grotenhermen, F. (2003). Pharmacokinetics and pharmacodynamics of cannabinoids. *Clin Pharmacokinet, 42*(4), 327-360. doi:10.2165/00003088-200342040-00003

Gunasekaran, N., Long, L. E., Dawson, B. L., Hansen, G. H., Richardson, D. P., Li, K. M., . . . McGregor, I. S. (2009). Reintoxication: the release of fat-stored Δ(9)-tetrahydrocannabinol (THC) into blood is enhanced by food deprivation or ACTH exposure. *British Journal of Pharmacology, 158*(5), 1330-1337. doi:10.1111/j.1476-5381.2009.00399.x

Hartman, R. L., Anizan, S., Jang, M., Brown, T. L., Yun, K. M., Gorelick, D. A., . . . Huestis, M. A. (2015). Cannabinoid disposition in oral fluid after controlled vaporizer administration with and without alcohol. *Forensic Toxicology, 33*(2), 260-278. doi:10.1007/s11419-015-0269-6

Hartman, R. L., Brown, T. L., Milavetz, G., Spurgin, A., Gorelick, D. A., Gaffney, G., & Huestis, M. A. (2016). Controlled vaporized cannabis, with and without alcohol: subjective effects and oral fluid-blood cannabinoid relationships. *Drug Test Anal, 8*(7), 690-701. doi:10.1002/dta.1839

Hoffman, J. (2016). Study finds sharp increase in marijuana exposure among Colorado children. *The New York Times*. Retrieved from https://www.nytimes.com/2016/07/26/health/marijuana-edibles-are-getting-into-colorado-childrens-hands-study-says.html

Hollister, L. E., Gillespie, H. K., Ohlsson, A., Lindgren, J. E., Wahlen, A., & Agurell, S. (1981). Do plasma concentrations of delta 9-tetrahydrocannabinol reflect the degree of intoxication? *J Clin Pharmacol, 21*(8-9 Suppl), 171s-177s.

Huestis, M. A. (2002). Cannabis (Marijuana) - Effects on Human Performance and Behavior. *Forensic Sci Rev, 14*(1-2), 15-60.

Huestis, M. A. (2007). Human Cannabinoid Pharmacokinetics. *Chemistry & biodiversity, 4*(8), 1770-1804. doi:10.1002/cbdv.200790152

Huestis, M. A., Milman, G., Mendu, D., Lee, D., Barnes, A. J., Schwope, D., . . . Desrosier, N. A. (2013). *Evaluation the on-site Draeger DrugTest 5000 in occasional and chronic frequent smokers following controlled cannabis smoking*. Retrieved from http://www.icadtsinternational.com/files/documents/2013_058.pdf

Huestis, M. A., Milman, G., Mendu, D., Lee, D., Barnes, A. J., Schwope, D. M., . . . Desrosiers, N. A. (2013). *Evaluation of the on-site Draeger DrugTest 5000 in occasional and chronic frequent smokers following controlled cannabis smoking.* Paper presented at the International Conference on Alcohol, Drugs and Traffic Safety (T2013), 20th, 2013, Brisbane, Queensland, Australia.

Huestis, M. A., & Smith, M. L. (2018). Cannabinoid Markers in Biological Fluids and Tissues: Revealing Intake. *Trends Mol Med, 24*(2), 156-172. doi:10.1016/j.molmed.2017.12.006
Kim, S. Y., Kim, H., Park, Y., Lim, J., Kim, J., Koo, S. H., & Kwon, G. C. (2017). Evaluation of an Automated Reader and Color Interpretation-Based Immunoassays for Multiplexed Drug-of-Abuse Testing in Urine. *J Anal Toxicol, 41*(5), 412-420. doi:10.1093/jat/bkx014
Lee, D., Milman, G., Barnes, A. J., Goodwin, R. S., Hirvonen, J., & Huestis, M. A. (2011). Oral fluid cannabinoids in chronic, daily cannabis smokers during sustained, monitored abstinence. *Clinical chemistry, 57*(8), 1127-1136.
Li, G., Chihuri, S., & Brady, J. E. (2017). Role of alcohol and marijuana use in the initiation of fatal two-vehicle crashes. *Annals of Epidemiology, 27*(5), 342-347.e341. doi:https://doi.org/10.1016/j.annepidem.2017.05.003
Li, K., Simons-Morton, B., Gee, B., & Hingson, R. (2016). Marijuana-, alcohol-, and drug-impaired driving among emerging adults: Changes from high school to one-year post-high school. *J Safety Res, 58*, 15-20. doi:10.1016/j.jsr.2016.05.003
Macdonald, S., Anglin-Bodrug, K., Mann, R. E., Erickson, P., Hathaway, A., Chipman, M., & Rylett, M. (2003). Injury risk associated with cannabis and cocaine use. *Drug Alcohol Depend, 72*(2), 99-115.
Milburn, M. (2017). DRUID. Retrieved from https://www.druidapp.com
Moore, C., Coulter, C., Uges, D., Tuyay, J., Van der Linde, S., Van Leeuwen, A., . . . Orbita Jr, J. (2011). Cannabinoids in oral fluid following passive exposure to marijuana smoke. *Forensic Science International, 212*(1-3), 227-230.
National Highway Traffic Safety Administration. (2016). *Fatality Analysis Reporting System (FARS) Analytical User's Manual 1974-2015*. Retrieved from Washington, D.C.: http://www.nber.org/fars/ftp.nhtsa.dot.gov/fars/FARS-DOC/Analytical%20User%20Guide/USERGUIDE-2015.pdf
Newmeyer, M. N., Swortwood, M. J., Andersson, M., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2017a). Cannabis Edibles: Blood and Oral Fluid Cannabinoid Pharmacokinetics and Evaluation of Oral Fluid Screening Devices for Predicting Delta9-Tetrahydrocannabinol in Blood and Oral Fluid following Cannabis Brownie Administration. *Clin Chem, 63*(3), 647-662. doi:10.1373/clinchem.2016.265371
Newmeyer, M. N., Swortwood, M. J., Andersson, M., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2017b). Cannabis Edibles: Blood and Oral Fluid Cannabinoid Pharmacokinetics and Evaluation of Oral Fluid Screening Devices for Predicting Delta(9)-Tetrahydrocannabinol in Blood and Oral Fluid following Cannabis Brownie Administration. *Clinical chemistry, 63*(3), 647-662. doi:10.1373/clinchem.2016.265371
Newmeyer, M. N., Swortwood, M. J., Barnes, A. J., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2016). Free and Glucuronide Whole Blood Cannabinoids' Pharmacokinetics after Controlled Smoked, Vaporized, and Oral Cannabis Administration in Frequent and Occasional Cannabis Users: Identification of Recent Cannabis Intake. *Clin Chem, 62*(12), 1579-1592. doi:10.1373/clinchem.2016.263475
Quantisal™ Oral Fluid Collection Device. (2018). Retrieved from https://www.alere.com/en/home/product-details/QuantisalOralFluidCollectionDevice-au.html
Rocky Mountain High Intensity Drug Trafficking Area. (2015). The Legalization of Marijuana in Colorado: The Impact.
Rogeberg, O., & Elvik, R. (2016). The effects of cannabis intoxication on motor vehicle collision revisited and revised. *Addiction, 111*(8), 1348-1359. doi:10.1111/add.13347
Salomonsen-Sautel, S., Min, S. J., Sakai, J. T., Thurstone, C., & Hopfer, C. (2014). Trends in fatal motor vehicle crashes before and after marijuana commercialization in Colorado. *Drug Alcohol Depend, 140*, 137-144. doi:10.1016/j.drugalcdep.2014.04.008

Scherer, J. N., Fiorentin, T. R., Borille, B. T., Pasa, G., Sousa, T. R. V., von Diemen, L., . . . Pechansky, F. (2017). Reliability of point-of-collection testing devices for drugs of abuse in oral fluid: A systematic review and meta-analysis. *Journal of Pharmaceutical and Biomedical Analysis, 143*, 77-85. doi:10.1016/j.jpba.2017.05.021

Subramanian, R. (2002). *Transitioning to multiple imputation - A New method to estimate missing blood alcohol concentration (BAC) in FARS*. Retrieved from Springfield, VA: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809403

Swortwood, M. J., Newmeyer, M. N., Abulseoud, O. A., Andersson, M., Barnes, A. J., Scheidweiler, K. B., & Huestis, M. A. (2017). On-site oral fluid Delta(9)-tetrahydrocannabinol (THC) screening after controlled smoked, vaporized, and oral cannabis administration. *Forensic Toxicology, 35*(1), 133-145. doi:10.1007/s11419-016-0348-3

Tefft, B. C., Arnold, L. S., & Grabowski, J. G. (2016). Prevalence of Marijuana Involvement in Fatal Crashes: Washington, 2010–2014.

Verstraete, A., Knoche, A., Jantos, R., Skopp, G., Gjerde, H., Vindenes, V., . . . Lillsunde, P. (2011). Per se limits: methods of defining cut-off values for zero tolerance.

Wall, M. E., Sadler, B. M., Brine, D., Taylor, H., & Perez-Reyes, M. (1983). Metabolism, disposition, and kinetics of delta-9-tetrahydrocannabinol in men and women. *Clin Pharmacol Ther, 34*(3), 352-363.

Walsh, J. M. (2008). New technology and new initiatives in US workplace testing. *Forensic Science International, 174*(2-3), 120-124. doi:10.1016/j.forsciint.2007.03.011

Walsh, J. M., Verstraete, A. G., Huestis, M. A., & Mørland, J. (2008). Guidelines for research on drugged driving. *Addiction, 103*(8), 1258-1268.

Wang, G. S., Roosevelt, G., Le Lait, M. C., Martinez, E. M., Bucher-Bartelson, B., Bronstein, A. C., & Heard, K. (2014). Association of unintentional pediatric exposures with decriminalization of marijuana in the United States. *Ann Emerg Med, 63*(6), 684-689. doi:10.1016/j.annemergmed.2014.01.017

Westin, A. A., Mjønes, G., Burchardt, O., Fuskevåg, O. M., & Slørdal, L. (2014). Can Physical Exercise or Food Deprivation Cause Release of Fat-Stored Cannabinoids? *Basic & Clinical Pharmacology & Toxicology, 115*(5), 467-471. doi:10.1111/bcpt.12235

Whitehill, J. M., Rivara, F. P., & Moreno, M. A. (2014). Marijuana-using drivers, alcohol-using drivers, and their passengers: prevalence and risk factors among underage college students. *JAMA Pediatr, 168*(7), 618-624. doi:10.1001/jamapediatrics.2013.5300

Wong, A., Keats, K., Rooney, K., Hicks, C., Allsop, D. J., Arnold, J. C., & McGregor, I. S. (2014). Fasting and exercise increase plasma cannabinoid levels in THC pre-treated rats: an examination of behavioural consequences. *Psychopharmacology (Berl), 231*(20), 3987-3996. doi:10.1007/s00213-014-3532-3

Wong, A., Montebello, M. E., Norberg, M. M., Rooney, K., Lintzeris, N., Bruno, R., . . . McGregor, I. S. (2013). Exercise increases plasma THC concentrations in regular cannabis users. *Drug Alcohol Depend, 133*(2), 763-767. doi:10.1016/j.drugalcdep.2013.07.031

Wood, E., Brooks-Russell, A., & Drum, P. (2016). Delays in DUI blood testing: Impact on cannabis DUI assessments. *Traffic Inj Prev, 17*(2), 105-108. doi:10.1080/15389588.2015.1052421

World Health Organization. (2017). Adolescent Health. Retrieved from http://www.who.int/topics/adolescent_health/en/

Zou, G. (2004). A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol, 159*(7), 702-706.

Chapter 3: Marijuana-Related Health System Contacts in Massachusetts

Introduction

Problems related to marijuana use may lead users to require medical care. This care seeking includes incidents in which someone seeks treatment for a cannabis use disorder, or could be related to an acute injury (e.g. from a cannabis-involved motor vehicle crash) or episode of marijuana-related illness. For this study, we brought together three sources of data to document the current several aspects of the current picture of health system contacts related to marijuana. Specifically, we sought to document the number and prevalence of (1) substance use treatment admissions for a primary diagnosis of cannabis use disorder; (2) emergency room and urgent care services due to marijuana, and (3) marijuana-related exposure calls received by the regional poison control center (PCC).

Since historical data is not available on use of emergency room and urgent care services for marijuana, we sought to obtain a 2017 point estimate. For treatment admissions and cannabis exposures (including unintentional exposure among youth 0-9) through poison control calls will capture trends associated with regulations, legislation and cultural shifts. As marijuana legalization of marijuana for adult use is implemented, these are valuable indicator that can serve as a benchmark against which future policy changes change be compared.

Methods

Treatment Episode Data

The national Substance Use and Mental Health Services Administration (SAMHSA) collects and publishes annual data episodes of substance use treatment in each U.S. This data includes information on the raw number and population adjusted number of admissions to substance abuse treatment by primary substance of abuse and by year. We compiled the number of marijuana-related treatment episodes for 2004-2014, with 2014 being the most recent year of data available. We also extracted information on alcohol, opioid, cocaine, and methamphetamine/amphetamine admissions for comparison purposes. We graphed the trend over time in population-adjusted admissions for marijuana, and the proportion of all admissions due to marijuana.

Population Survey of Massachusetts Adults

We analyzed the survey conducted as part of the MBHS included questions on seeking emergency or urgent care related to marijuana use. Briefly, we conducted a population-based, mail and Internet survey of Massachusetts residents age 18 years and older. This study was approved by the Institutional Review Board at the Massachusetts Department of Public Health. The survey instrument can be found in Appendix A.

Details on the methods of survey design, data collection, measures, and statistical procedures, including survey weighting, can be found in Task 1, Chapter 2. In addition to the measures described therein, several questions were added to the survey for the purpose of addressing use of emergency room or urgent care services related to substance use.

For individuals who reported yes to using a particular substance (alcohol, marijuana, or other substances) in the past 30 days, the survey asked if they had utilized emergency room or urgent care services in relation to that substance within the past year.

Poison Control Center Exposure Calls

It can be difficult to distinguish, from secondary data, the intentionality of an exposure. For example, if teenagers intentionally experiment with marijuana but have adverse reactions, they may call poison control claiming unintentional exposure. Therefore, prior studies have coded all exposures under the age of 9 years as unintentional.

As restricting cases to children 9 years old and under has been utilized in previous studies to ensure the analysis is accurately assessing unintentional exposures and exclude adolescents, this study looked at this age range separately as well as examined cases in different age groups. Other age groups of interest revolved around youth and adolescents. As adolescence varies by individual, sex and national differences, this analysis used age categories of 10-19 years, based on the World Health Organization identification as this time period as the general span of adolescents (World Health Organization, 2017). We also used a category for 20-24 years as this age span is described as late adolescence in the United States (Arnett & Tanner, 2004) and utilized in similar studies in Colorado (Wang et al., 2014).

Unknown age includes teen, unknown adult, unknown 20's and unknown. Adults 30 and over with decade specification but no specific age they were assigned the median of their decade, e.g. 50's was assigned 55. A listing of marijuana-involved exposure calls and aggregate numbers of all PCC exposure calls by age group and by year was provided by the PCC for calls originating from within Massachusetts. We excluded calls from Rhode Island.

We included the following product codes: 310124 Marijuana: Concentrated Extract (Including Oils and Tinctures); 083000 Marijuana: Dried Plant; 310121 Marijuana: Edible Preparation, 310122 Marijuana: Oral Capsule or Pill Preparation, 310126 Marijuana: Other or Unknown Preparation, 200618 Marijuana: Pharmaceutical Preparation, 310125 Marijuana: Topical Preparation, 310123 Marijuana: Undried Plant, 310096 eCigarettes: Marijuana Device Flavor Unknown, 310034 eCigarettes: Marijuana Device With Added Flavors, 310033 eCigarettes: Marijuana Device Without Added Flavors, 310097 eCigarettes: Marijuana Liquid Flavor Unknown, 310036 eCigarettes: Marijuana Liquid With Added Flavors, 310035 eCigarettes: Marijuana Liquid Without Added Flavors. There were five cases exposed to two marijuana codes: one exposure always being dried plant there was 1 synthetic, 2 edibles, 1 concentrate, and 1 other/unknown. These were recoded as 2 marijuana codes. No combination of marijuana preparations exceeded two preparations, for example dried plant and edible. For calls involving multiple substances, we did not have the information on what other substances were involved, for example acetometaphin.

To explore population fluctuations that could influence prevalence, we examined the percent change in the MA population in 2007, 2010, and 2016 within age categories, using census data. If the change was less than 10%, we used 2010 census data to calculate calls per 100,000 people. There was a greater than 10% change in 25-34, 35-44, 60-64, and 65-74 year age groups, but when collapsed into adults 25 and older, there was no significant change. We, therefore, used 2010 census data as the denominator for population prevalence rates.
We graphed trend lines for the percentage of all PCC calls due to marijuana exposure, and graphed the number of exposure calls due to various preparations of marijuana. Medical marijuana became legal in Massachusetts in late 2012, so we examined whether the proportion of all PCC calls due to marijuana was statistically significantly different before this change (2007-2012) versus after (2013-2016). Chi-squared tests or Fisher's exact tests were used for those analyses. All analyses were stratified by age group.

Results

Episodes of Marijuana-Related Substance Use Treatment

As shown in Table 1, the number of admissions to substance use treatment for marijuana was 2652 in 2014. This represents an increase from 2012 and 2013 levels, but a decrease from the historic levels in the 2004-2010. The prevalence of marijuana-related admissions to treatment was 45 per 100,000 in 2014. This was consistent in the last few years, and a decline from peak levels in 2006-2005 (Figure 1).

Table 1. Number of Substance Abuse Treatment Admissions in Massachusetts by Primary Sub-Substance of Abuse, Age 12+, 2004-2014

	Year										
Primary Substance	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
marijuana	3144	3372	4957	4360	3362	3073	3157	2614	2501	2357	2652
alcohol	20421	20734	37337	36570	32435	32153	31299	28587	27678	26786	27619
opioids	29086	28509	41097	42014	39568	41700	40306	41723	46200	50482	50116
cocaine	3643	4223	7446	6597	4828	4066	3519	3036	2758	2461	2319
meth/amp	119	152	190	163	94	70	126	90	115	160	182
Total	53269	53618	86070	85344	76925	77989	75250	73436	76751	79889	80236

Note: other substances of abuse are not included in this table.
*meth/amp=methamphetamine/amphetamine.

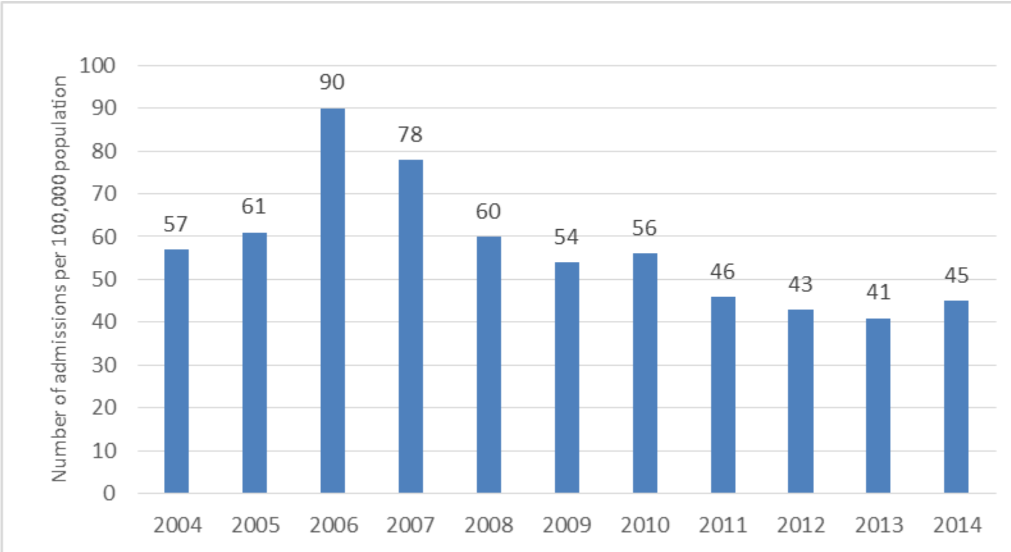


Figure 1. Massachusetts Admissions to Substance Use Treatment with Marijuana as Primary Substance of Abuse, Age 12+, 2004-2014

As shown in Figure 2, the proportion of substance abuse treatment admissions due to marijuana use has remained at less than 5% of all admissions. However, it is important to note that in the midst of the opioid epidemic, which has taxed the capacity of the treatment system, the proportion of admissions due to all other substances would inherently be reduced.

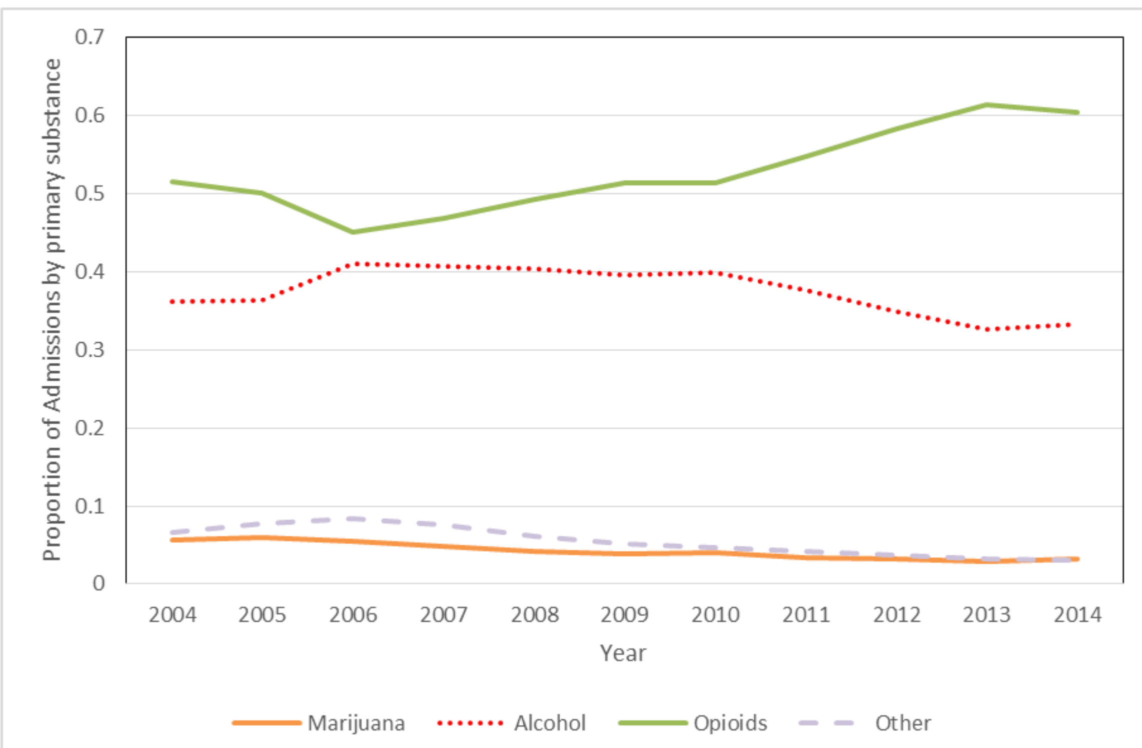


Figure 2. Proportion of Substance Abuse Treatment Admissions by Primary Substance of Abuse, 2004-2014

Substance Use-Related Emergency Care

Among those who used marijuana in the past 30 days, no respondents reported marijuana-related use of emergency room or urgent care services in the prior year. Nearly 70% of Massachusetts adults used alcohol in the past 30 days. Among this group, 1.7% reported use of emergency use of healthcare due to alcohol in the past year. Additionally, 4.1% of the population reported past 30-day use of other substances (e.g. cocaine, opioids, etc.); 4.7% of these individuals sought emergency care related to their substance use, although we note that this estimate is based on fewer than five individuals in the sample and should be interpreted with caution.

Marijuana-Related Exposure Calls to the Poison Control Center

During the 10-year study period (2007-2016) there were 641 calls to the PCC that included marijuana exposure (Table 2) with an upward trend over time (Figure 3). The overall period prevalence from 2007-2016 was 9.4 per 100,000 population. In 2016, there were 78 calls to the PCC with marijuana exposure. Six of these calls pertained to marijuana exposure in youth age 0-9 years, 33 among youth 10-19 years, 12 among young adults age 20-24 years, and 27 among individuals age 25 years and older. These numbers correspond to a prevalence of 0.79 per 100,000 among children age 0-9 years was; 3.8 among 10-19 year olds, 2.5 among 20-24, and 0.6 per 100,000 among those over age 25 years.

For youth under age 18, the proportion of all PCC calls that were due to marijuana, by age group, is shown in Figure 3. The proportion was highest for youth between 10-19 years. Although the magnitude is small, with the highest proportion being under 0.5% (among 10-17 year olds), this is concerning, since the youngest children 0-9 years are being impacted at increasingly levels, presumably through unintentional exposure (Figure 3). We also observed increasing proportions of calls due to marijuana for adults (Figure 4).

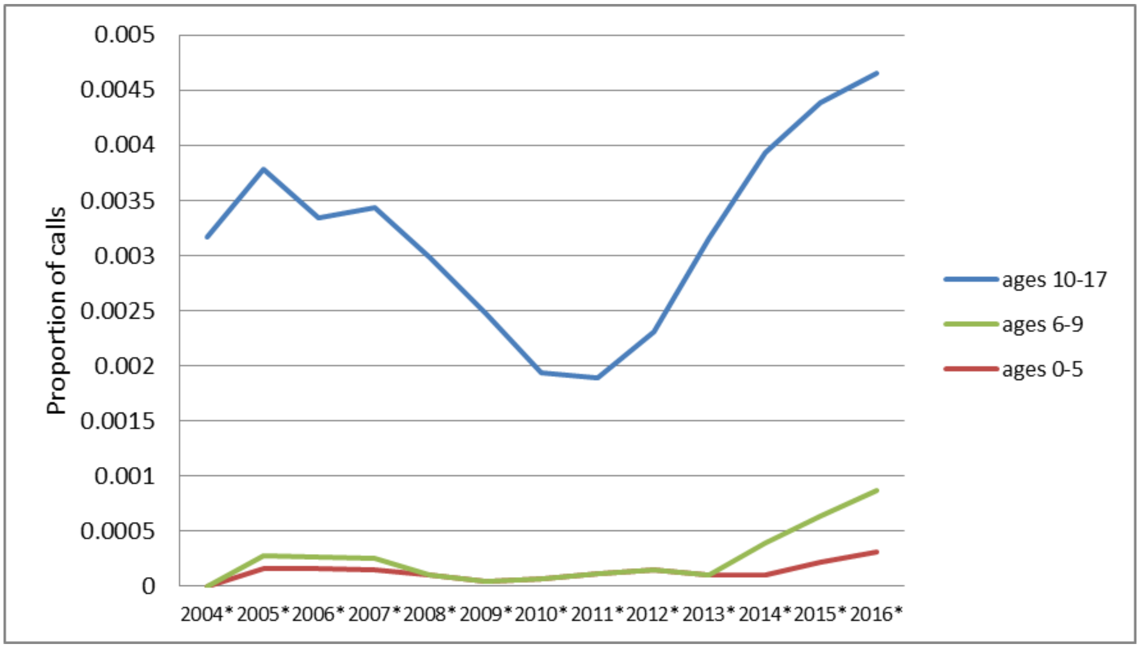


Figure 3. Proportion of MA Poison Control Calls due to Marijuana, Youth Age 0-17, 3-Year Moving Average, and 2004-2016

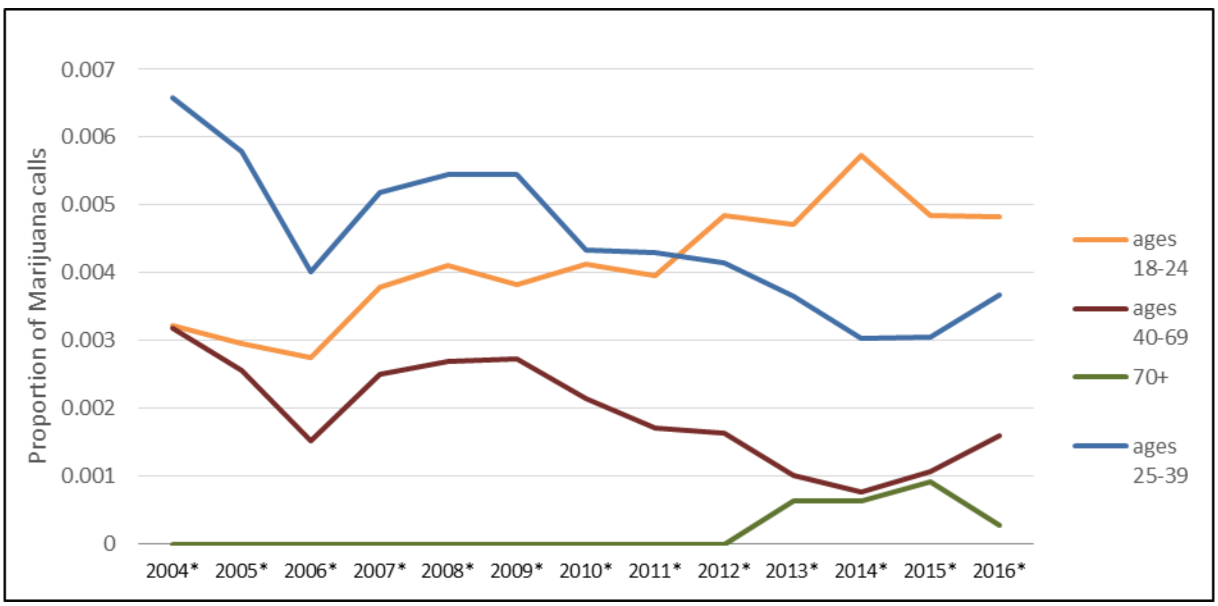


Figure 4. Proportion of MA Poison Control Calls Related to Marijuana Exposure, Adults 18+ Years, 3-Year Moving Average, 2004-2016

Table 2. Demographics and Medical Outcomes of Cannabis-Involved Exposure Calls to the Poison Control Center, Massachusetts, 2007-2016

	Frequency	Percent	
Sex			
Female	253	39.47	
Male	388	60.53	
Total	641	100	
Age			
0-9 years	27	4.21	
10-19 years	257	40.09	
20-24	121	18.88	
25-29	50	7.8	
30's	79	12.32	
40's	53	8.27	
50's	22	3.43	
60's	6	0.94	
70's+	3	0.47	
Unknown	23	3.59	
Total	641	100	
Medical Outcome			**No. Calls with One Code**[‡]
Death	3	0.47	0 (0%)
major effect	56	8.74	3 (5.4%)
minor effect	143	22.31	31 (22%)
moderate effect	277	43.21	53 (19%)
no effect	36	5.62	9 (25%)
not followed, minimal effects possible	29	4.52	14 (48%)
not followed, non-toxic	4	0.62	4 (100%)
unable to follow, judged potentially toxic	87	13.57	55 (63%)
unrelated effect, exposure probably not responsible for effects	6	0.94	3(50%)
Total	641	100	

One substance was a non-synthetic preparation of Marijuana; Proportion in parentheses represents the proportion of all cannabis-involved calls within each medical outcome that were due to only one cannabis code.

Table 2 shows the medical outcomes reported by PCC professionals. Not surprisingly, there was a higher proportion of calls involving a death or major effect for calls involving multiple substances (as many as 14 involved) compared to calls involving only one cannabis code. The multi-substance calls included substances that were not marijuana. We examined whether there was an increase in the proportion of PCC calls due to marijuana after medical marijuana was legalized in Massachusetts versus before.

Results from chi-squared and Fisher's exact tests indicated that although the percentages are small, there was a higher proportion of PCC calls due to marijuana exposure in 2013-2016 compared to 2007-2012 for children age 0-5 years ($p=0.001$), children 6-9 years ($p=0.017$) and youth age 10-20 ($p=0.001$). See Table 3.

When examining the different marijuana product codes involved in calls to the PCC, we found that over time and across age groups, most calls involved dried marijuana plant. The next most common preparation involved was edible preparations, more frequently seen after 2012 (Figures 5-7).

Table 3. Differences in Proportions of Marijuana-Related Poison Control Center Calls, Pre- versus Post-2012

	2007-2012		2013-2016		total	
Ages 0-5						
	n	%	n	%	n	p-value
Marijuana calls	7	0.008	16	0.035	23	0.001
Non-marijuana calls	84,441	99.992	46,305	99.965	130,846	
Total calls	84,448	100.000	46,321	100.000	130869	
Ages 6-9						
	n	%	n	%	n	p-value
Marijuana calls	0	0.000	4	0.043	4	0.017
Non-Marijuana calls	16,431	100.000	9,388	99.957	25,919	
Total calls	16431	100.000	9392	100.000	25923	
Ages 10-20						
	n	%	n	%	n	p-value
Marijuana calls	155	0.291	129	0.439	284	0.001
Non-Marijuana calls	53,286	99.709	29,288	99.561	82,574	
Total calls	53441	100.000	29417	100.000	82858	
Ages 21+						
	n	%	n	%	n	p-value
Marijuana calls	197	0.332	110	0.278	307	0.145
Non-Marijuana calls	59,107	99.668	39,450	99.722	98,557	
Total calls	59304	100.000	39560	100.000	98864	

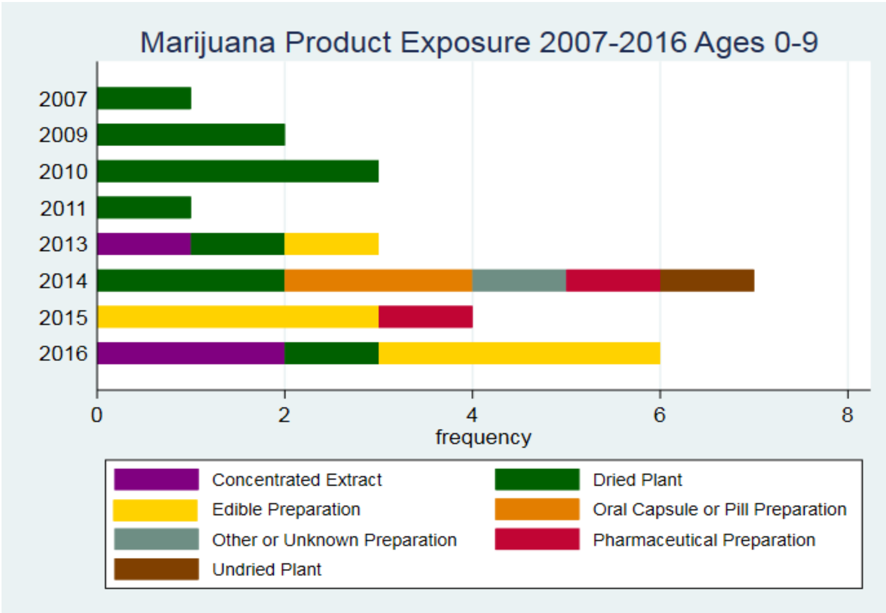


Figure 5. Frequency of Poison Control Center Reported Marijuana Exposures by Product Code, 2007-2016, Age 0-9 Years

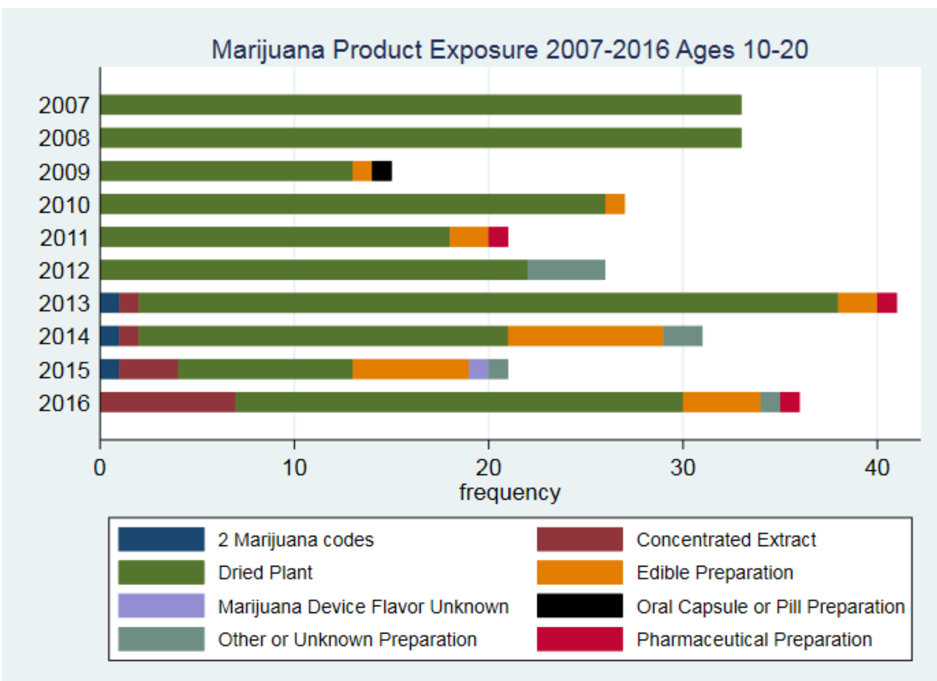


Figure 6. Frequency of Poison Control Center Reported Marijuana Exposures by Product Code, 2007-2016, Age 10-20 Years

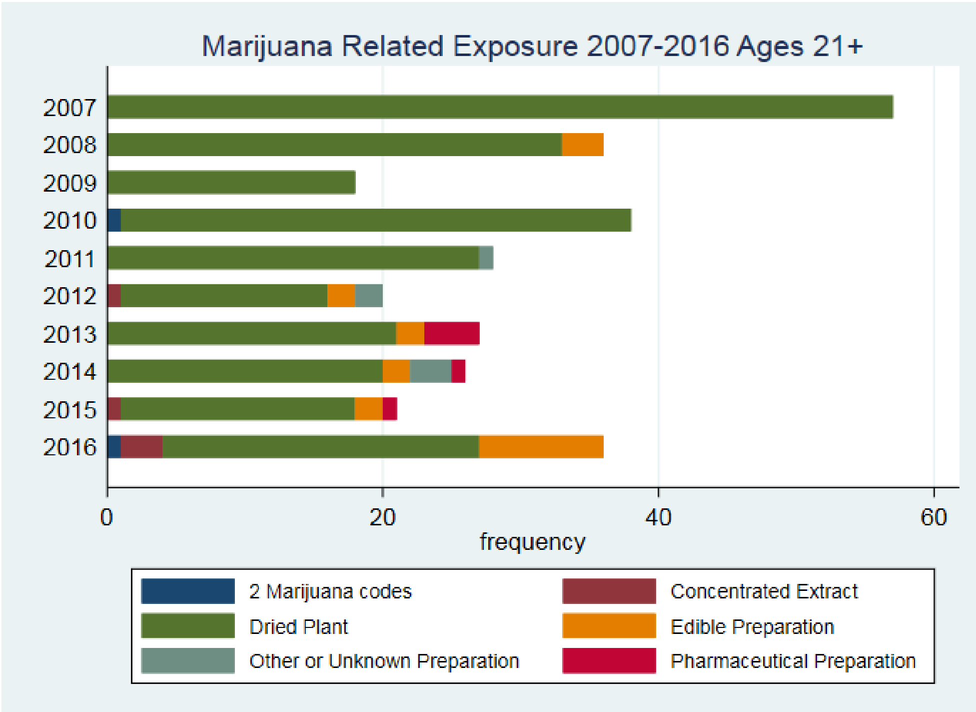


Figure 7. Frequency of Poison Control Center Reported Marijuana Exposures by Product Code, 2007-2016, Age 21 Years and Older

Discussion

In MA from 2005-2016, the period prevalence was 3.5 per 100,000 in children age 0-9 years. A study of Colorado between 2005 and 2011 found cases of children under the age of 9 who had Poison control calls for marijuana related exposures was 6.6 per 100,000; this was compared to generally less than 2 calls per 100,000 in states without similar marijuana legislation (Wang et al., 2014). That study raised discussions about whether the finding of increased prevalence in a state with medical marijuana at the time was due to increased exposure or less stigma among parents or caregivers calling to report such an exposure (Hoffman, 2016). Our data indicated that there was a statistically significant increase in the proportion of calls to the PCC that were related to marijuana after medical marijuana was legalized in Massachusetts.

Children age 0-9 years accounted for less than 5% of the calls to the PCC due to marijuana exposure during the study period, whereas youth aged 10-19 years accounted for 40% of marijuana-related calls.

References

Alcohol and Drug Abuse Institute. (2013). What is Cannabis? Retrieved from http://learnaboutmarijuanawa.org/factsheets/whatiscannabis.htm

Alere DDS®2 Mobile Test System: Rapid Screening for Drugs of Abuse in Oral Fluid. (2018). Retrieved from https://www.alere.com/en/home/product-details/dds2-mobile-test-system.html#

Allen, K. R. (2011). Screening for drugs of abuse: which matrix, oral fluid or urine? *Annals of Clinical Biochemistry, 48*(6), 531-541.

Arnett, J. J., & Tanner, J. L. (Eds.). (2004). *Emerging Adulthood: The Winding Road from the Late Teens through the Twenties*. New York, NY: Oxford University Press.

Arria, A. M., Caldeira, K. M., Vincent, K. B., Garnier-Dykstra, L. M., & O'Grady, K. E. (2011). Substance-related traffic-risk behaviors among college students. *Drug Alcohol Depend, 118*(2-3), 306-312. doi:10.1016/j.drugalcdep.2011.04.012

Asbridge, M., Hayden, J. A., & Cartwright, J. L. (2012). Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. *BMJ, 344*, e536.

Banta-Green, C., Rowhani-Rahbar, A., Ebel, B. E., Andris, L. M., & Qiu, Q. (2016). Cannabis Use among Drivers Suspected of Driving Under the Influence or Involved in Collisions: Analyses of Washington State Patrol Data.

Berning, A., & Smither, D. (2014). *Understanding the Limitations of Drug Test Information, Reporting, and Testing Practices in Fatal Crashes*. Washington, D.C.: U. S. D. o. Transportation. Retrieved from

Blencowe, T., Pehrsson, A., & Lillsunde, P. (2010). *Analytical evaluation of oral fluid screening devices and preceding selection procedures*. A. a. M. Driving Under the Influence of Drugs. Retrieved from https://www.bast.de/Druid/EN/deliverales-list/downloads/Deliverable_3_2_2.pdf?__blob=publicationFile&v=1.

Bondallaz, P., Favrat, B., Chtioui, H., Fornari, E., Maeder, P., & Giroud, C. (2016). Cannabis and its effects on driving skills. *Forensic Sci Int, 268*, 92-102. doi:https://doi.org/10.1016/j.forsciint.2016.09.007

Bosker, W. M., & Huestis, M. A. (2009). Oral fluid testing for drugs of abuse. *Clin Chem, 55*(11), 1910-1931.

Chihuri, S., Li, G., & Chen, Q. (2017). Interaction of marijuana and alcohol on fatal motor vehicle crash risk: a case-control study. *Inj Epidemiol, 4*(1), 8. doi:10.1186/s40621-017-0105-z

Compton, R. (2017). *Marijuana-Impaired Driving A Report to Congress*. Washington, DC. Retrieved from

Davis, K. C., Allen, J., Duke, J., Nonnemaker, J., Bradfield, B., Farrelly, M. C., . . . Novak, S. (2016). Correlates of Marijuana Drugged Driving and Openness to Driving While High: Evidence from Colorado and Washington. *PLoS One, 11*(1), e0146853. doi:10.1371/journal.pone.0146853

Department of Health and Environment, C. Adult marijuana use trends. *Monitoring trends in adult marijuana use.*

Department of Health and Human Services. (2015). *Mandatory Guidelines for Federal Workplace Drug Testing Programs*. Retrieved from

Dräger DrugTest® 5000: Analysis system for detecting drugs. (2018). Retrieved from https://www.draeger.com/Library/Content/drugtest_5000_pi_9041006_en.pdf

Drummer, O. H. (2010). Forensic toxicology. *Exs, 100*, 579-603.

Edwards, L. D., Smith, K. L., & Savage, T. (2017). Drugged Driving in Wisconsin: Oral Fluid Versus Blood. *J Anal Toxicol, 41*(6), 523-529. doi:10.1093/jat/bkx051

Gentili, S., Solimini, R., Tittarelli, R., Mannocchi, G., & Busardo, F. P. (2016). A Study on the Reliability of an On-Site Oral Fluid Drug Test in a Recreational Context. *J Anal Methods Chem, 2016*, 1234581. doi:10.1155/2016/1234581

Gentili, S., Solimini, R., Tittarelli, R., Mannocchi, G., & Busardò, F. P. (2016). A Study on the Reliability of an On-Site Oral Fluid Drug Test in a Recreational Context. *J Anal Methods Chem, 2016*, 1234581. doi:10.1155/2016/1234581

Grotenhermen, F. (2003). Pharmacokinetics and pharmacodynamics of cannabinoids. *Clin Pharmacokinet, 42*(4), 327-360. doi:10.2165/00003088-200342040-00003

Gunasekaran, N., Long, L. E., Dawson, B. L., Hansen, G. H., Richardson, D. P., Li, K. M., . . . McGregor, I. S. (2009). Reintoxication: the release of fat-stored Δ(9)-tetrahydrocannabinol (THC) into blood is enhanced by food deprivation or ACTH exposure. *British Journal of Pharmacology, 158*(5), 1330-1337. doi:10.1111/j.1476-5381.2009.00399.x

Hartman, R. L., Anizan, S., Jang, M., Brown, T. L., Yun, K. M., Gorelick, D. A., . . . Huestis, M. A. (2015). Cannabinoid disposition in oral fluid after controlled vaporizer administration with and without alcohol. *Forensic Toxicology, 33*(2), 260-278. doi:10.1007/s11419-015-0269-6

Hartman, R. L., Brown, T. L., Milavetz, G., Spurgin, A., Gorelick, D. A., Gaffney, G., & Huestis, M. A. (2016). Controlled vaporized cannabis, with and without alcohol: subjective effects and oral fluid-blood cannabinoid relationships. *Drug Test Anal, 8*(7), 690-701. doi:10.1002/dta.1839

Hoffman, J. (2016). Study finds sharp increase in marijuana exposure among Colorado children. *The New York Times*. Retrieved from https://www.nytimes.com/2016/07/26/health/marijuana-edibles-are-getting-into-colorado-childrens-hands-study-says.html

Hollister, L. E., Gillespie, H. K., Ohlsson, A., Lindgren, J. E., Wahlen, A., & Agurell, S. (1981). Do plasma concentrations of delta 9-tetrahydrocannabinol reflect the degree of intoxication? *J Clin Pharmacol, 21*(8-9 Suppl), 171s-177s.

Huestis, M. A. (2002). Cannabis (Marijuana) - Effects on Human Performance and Behavior. *Forensic Sci Rev, 14*(1-2), 15-60.

Huestis, M. A. (2007). Human Cannabinoid Pharmacokinetics. *Chemistry & biodiversity, 4*(8), 1770-1804. doi:10.1002/cbdv.200790152

Huestis, M. A., Milman, G., Mendu, D., Lee, D., Barnes, A. J., Schwope, D., . . . Desrosier, N. A. (2013). *Evaluation the on-site Draeger DrugTest 5000 in occasional and chronic frequent smokers following controlled cannabis smoking*. Retrieved from http://www.icadtsinternational.com/files/documents/2013_058.pdf.

Huestis, M. A., Milman, G., Mendu, D., Lee, D., Barnes, A. J., Schwope, D. M., . . . Desrosiers, N. A. (2013). *Evaluation of the on-site Draeger DrugTest 5000 in occasional and chronic frequent smokers following controlled cannabis smoking.* Paper presented at the International Conference on Alcohol, Drugs and Traffic Safety (T2013), 20th, 2013, Brisbane, Queensland, Australia.

Huestis, M. A., & Smith, M. L. (2018). Cannabinoid Markers in Biological Fluids and Tissues: Revealing Intake. *Trends Mol Med, 24*(2), 156-172. doi:10.1016/j.molmed.2017.12.006

Kim, S. Y., Kim, H., Park, Y., Lim, J., Kim, J., Koo, S. H., & Kwon, G. C. (2017). Evaluation of an Automated Reader and Color Interpretation-Based Immunoassays for Multiplexed Drug-of-Abuse Testing in Urine. *J Anal Toxicol, 41*(5), 412-420. doi:10.1093/jat/bkx014

Lee, D., Milman, G., Barnes, A. J., Goodwin, R. S., Hirvonen, J., & Huestis, M. A. (2011). Oral fluid cannabinoids in chronic, daily cannabis smokers during sustained, monitored abstinence. *Clin Chem, 57*(8), 1127-1136.

Li, G., Chihuri, S., & Brady, J. E. (2017). Role of alcohol and marijuana use in the initiation of fatal two-vehicle crashes. *Annals of Epidemiology, 27*(5), 342-347.e341. doi:https://doi.org/10.1016/j.annepidem.2017.05.003

Li, K., Simons-Morton, B., Gee, B., & Hingson, R. (2016). Marijuana-, alcohol-, and drug-impaired driving among emerging adults: Changes from high school to one-year post-high school. *J Safety Res, 58*, 15-20. doi:10.1016/j.jsr.2016.05.003

Macdonald, S., Anglin-Bodrug, K., Mann, R. E., Erickson, P., Hathaway, A., Chipman, M., & Rylett, M. (2003). Injury risk associated with cannabis and cocaine use. *Drug Alcohol Depend, 72*(2), 99-115.

Milburn, M. (2017). DRUID. Retrieved from https://www.druidapp.com

Moore, C., Coulter, C., Uges, D., Tuyay, J., Van der Linde, S., Van Leeuwen, A., . . . Orbita Jr, J. (2011). Cannabinoids in oral fluid following passive exposure to marijuana smoke. *Forensic Sci Int, 212*(1-3), 227-230.

National Highway Traffic Safety Administration. (2016a). *2016 FARS/CRSS Coding and Validation Manual*. Washington, D.C: National Highway Traffic Safety Administration. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812449.

National Highway Traffic Safety Administration. (2016b). *Fatality Analysis Reporting System (FARS) Analytical User's Manual 1974-2015*. Washington, D.C.: U. S. D. o. Transportation. Retrieved from http://www.nber.org/fars/ftp.nhtsa.dot.gov/fars/FARS-DOC/Analytical%20User%20Guide/USERGUIDE-2015.pdf.

Newmeyer, M. N., Swortwood, M. J., Andersson, M., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2017a). Cannabis Edibles: Blood and Oral Fluid Cannabinoid Pharmacokinetics and Evaluation of Oral Fluid Screening Devices for Predicting Delta9-Tetrahydrocannabinol in Blood and Oral Fluid following Cannabis Brownie Administration. *Clin Chem, 63*(3), 647-662. doi:10.1373/clinchem.2016.265371

Newmeyer, M. N., Swortwood, M. J., Andersson, M., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2017b). Cannabis Edibles: Blood and Oral Fluid Cannabinoid Pharmacokinetics and Evaluation of Oral Fluid Screening Devices for Predicting Delta(9)-Tetrahydrocannabinol in Blood and Oral Fluid following Cannabis Brownie Administration. *Clin Chem, 63*(3), 647-662. doi:10.1373/clinchem.2016.265371

Newmeyer, M. N., Swortwood, M. J., Barnes, A. J., Abulseoud, O. A., Scheidweiler, K. B., & Huestis, M. A. (2016). Free and Glucuronide Whole Blood Cannabinoids' Pharmacokinetics after Controlled Smoked, Vaporized, and Oral Cannabis Administration in Frequent and Occasional Cannabis Users: Identification of Recent Cannabis Intake. *Clin Chem, 62*(12), 1579-1592. doi:10.1373/clinchem.2016.263475

Quantisal™ Oral Fluid Collection Device. (2018). Retrieved from https://www.alere.com/en/home/product-details/QuantisalOralFluidCollectionDevice-au.html

Rocky Mountain High Intensity Drug Trafficking Area. (2015). The Legalization of Marijuana in Colorado: The Impact.

Rogeberg, O., & Elvik, R. (2016). The effects of cannabis intoxication on motor vehicle collision revisited and revised. *Addiction, 111*(8), 1348-1359. doi:10.1111/add.13347

Salomonsen-Sautel, S., Min, S. J., Sakai, J. T., Thurstone, C., & Hopfer, C. (2014). Trends in fatal motor vehicle crashes before and after marijuana commercialization in Colorado. *Drug Alcohol Depend, 140*, 137-144. doi:10.1016/j.drugalcdep.2014.04.008

Scherer, J. N., Fiorentin, T. R., Borille, B. T., Pasa, G., Sousa, T. R. V., von Diemen, L., . . . Pechansky, F. (2017). Reliability of point-of-collection testing devices for drugs of abuse in oral fluid: A systematic review and meta-analysis. *Journal of Pharmaceutical and Biomedical Analysis, 143*, 77-85. doi:10.1016/j.jpba.2017.05.021

Subramanian, R. (2002). *Transitioning to multiple imputation - A New method to estimate missing blood alcohol concentration (BAC) in FARS*. Springfield, VA: National Center for

Statistics and Analysis. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809403.
Swortwood, M. J., Newmeyer, M. N., Abulseoud, O. A., Andersson, M., Barnes, A. J., Scheidweiler, K. B., & Huestis, M. A. (2017). On-site oral fluid Delta(9)-tetrahydrocannabinol (THC) screening after controlled smoked, vaporized, and oral cannabis administration. *Forensic Toxicology, 35*(1), 133-145. doi:10.1007/s11419-016-0348-3
Tefft, B. C., Arnold, L. S., & Grabowski, J. G. (2016). Prevalence of Marijuana Involvement in Fatal Crashes: Washington, 2010–2014.
Verstraete, A., Knoche, A., Jantos, R., Skopp, G., Gjerde, H., Vindenes, V., . . . Lillsunde, P. (2011). Per se limits: methods of defining cut-off values for zero tolerance.
Wall, M. E., Sadler, B. M., Brine, D., Taylor, H., & Perez-Reyes, M. (1983). Metabolism, disposition, and kinetics of delta-9-tetrahydrocannabinol in men and women. *Clin Pharmacol Ther, 34*(3), 352-363.
Walsh, J. M. (2008). New technology and new initiatives in US workplace testing. *Forensic Sci Int, 174*(2-3), 120-124. doi:10.1016/j.forsciint.2007.03.011
Walsh, J. M., Verstraete, A. G., Huestis, M. A., & Mørland, J. (2008). Guidelines for research on drugged driving. *Addiction, 103*(8), 1258-1268.
Wang, G. S., Roosevelt, G., Le Lait, M. C., Martinez, E. M., Bucher-Bartelson, B., Bronstein, A. C., & Heard, K. (2014). Association of unintentional pediatric exposures with decriminalization of marijuana in the United States. *Ann Emerg Med, 63*(6), 684-689. doi:10.1016/j.annemergmed.2014.01.017
Westin, A. A., Mjønes, G., Burchardt, O., Fuskevåg, O. M., & Slørdal, L. (2014). Can Physical Exercise or Food Deprivation Cause Release of Fat-Stored Cannabinoids? *Basic & Clinical Pharmacology & Toxicology, 115*(5), 467-471. doi:10.1111/bcpt.12235
Whitehill, J. M., Rivara, F. P., & Moreno, M. A. (2014). Marijuana-using drivers, alcohol-using drivers, and their passengers: prevalence and risk factors among underage college students. *JAMA Pediatr, 168*(7), 618-624. doi:10.1001/jamapediatrics.2013.5300
Wong, A., Keats, K., Rooney, K., Hicks, C., Allsop, D. J., Arnold, J. C., & McGregor, I. S. (2014). Fasting and exercise increase plasma cannabinoid levels in THC pre-treated rats: an examination of behavioural consequences. *Psychopharmacology (Berl), 231*(20), 3987-3996. doi:10.1007/s00213-014-3532-3
Wong, A., Montebello, M. E., Norberg, M. M., Rooney, K., Lintzeris, N., Bruno, R., . . . McGregor, I. S. (2013). Exercise increases plasma THC concentrations in regular cannabis users. *Drug Alcohol Depend, 133*(2), 763-767. doi:10.1016/j.drugalcdep.2013.07.031
Wood, E., Brooks-Russell, A., & Drum, P. (2016). Delays in DUI blood testing: Impact on cannabis DUI assessments. *Traffic Inj Prev, 17*(2), 105-108. doi:10.1080/15389588.2015.1052421
World Health Organization. (2017). Adolescent Health. Retrieved from http://www.who.int/topics/adolescent_health/en/
Zou, G. (2004). A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol, 159*(7), 702-706.

Task 3: Economic and Fiscal Impacts

Chapter 1: From Medical to Retail Marijuana: Estimating Fiscal Effects of Legalization In Massachusetts

Abstract

Background

In 2016, Massachusetts voters approved a ballot measure to legalize broad adult use of marijuana. As part of the 2017-2018 Massachusetts Marijuana Baseline Health Study, we estimated fiscal impacts of legalization for state and local governments. We developed a model to estimate changes expected in four key domains within the first two years of retail sales: tax revenue from marijuana purchases (based on a 20% combined sales, excise, and local tax rate); regulatory oversight; law enforcement activities; and public health effects.

Methods

Estimates of revenue or savings and costs or losses were derived from the literature (restricted to impacts attributable to legalization); expert interviews; and secondary sources (on marijuana pricing, marijuana use prevalence, regulatory costs and revenue, public health and safety outcomes, and Massachusetts population size and demographics). For each measure, we defined a range of values, then used Monte Carlo simulation to randomly choose a value to calculate post-legalization estimate. We calculated post-legalization impacts by combining information on pre-legalization estimates with estimates of change due to legalization. We summed estimates across all measures and domains to obtain an overall impact estimate.

Results

In our main model, which included measures that were major drivers of budgetary impacts (sales and business tax revenue, regulatory costs and revenue, and savings due to reduced marijuana-related law enforcement), we projected a gain of $215.8 million to the state budget. In a supplemental model that added in public health impacts thought to be less definitive or immediate, we projected an additional gain of $65.3 million, yielding a total impact of $281.1 million. Local tax revenue estimates (derived using local data on marijuana use prevalence and pricing, when available) ranged from a median of $63,000 for suburban cities and towns to $583,000 for urban cities.

Discussion

The primary driver of fiscal gains (accounting for 53% of the total impact) was sales and excise tax revenue collected on retail marijuana purchases. Other major contributors included new business tax revenue from marijuana dispensaries and increased individual income tax revenue due to worker productivity gains among older adults who are able to control debilitating medical conditions with marijuana.

Background

In November 2016, Massachusetts voters approved a ballot measure to legalize adult use of marijuana, joining a growing list of states approving and implementing similar measures in the past five years. The adult use of marijuana program will build on the medical marijuana program that has been operating in Massachusetts since 2013, serving nearly 50,000 active patients as of January 2018.[1] The program will also build on the experiences from other states that have legalized marijuana in recent years. However, given that retail sales of marijuana have only been legal in the United States for about four years, there is a sparse body of literature on the causal impacts of marijuana on a host of fiscal, health, public safety, and criminal justice outcomes. To better understand marijuana use in the state and to project fiscal impacts associated with retail sales, the state legislated that the Massachusetts Department of Public Health (MDPH) conduct the Marijuana Baseline Health Study (MBHS). The study examines the use, methods of consumption, and perceptions of marijuana; impaired driving and hospitalization related to marijuana use; and economic and fiscal impacts for state and local governments.[2] In this report, we address the third aim to estimate the fiscal impacts of moving from a medical marijuana program to broad adult use. We focus on four key domains: (1) tax revenue from marijuana sales, (2) regulatory oversight, (3) law enforcement activities, and (4) public health effects.

Retail sales of marijuana are planned to begin in July 2018, after legislation was passed in December 2016 to delay implementation of the program by six months.[3] Whereas the original ballot measure included a 3.75% excise tax, 6.25% state sales tax, and an optional local tax up to 2%, for a maximum tax rate of 12%, the state legislature later passed a bill to increase the excise tax to 10.75% and the maximum local tax to 3%, yielding a total maximum tax rate of 20%.[4] A share of the revenues collected by the state will be devoted to (1) public and behavioral health, (2) public safety, (3) municipal police training, (4) the Prevention and Wellness Trust Fund, and (5) a host of services for "economically-disadvantaged persons in communities disproportionately impacted by high rates of arrest and incarceration for marijuana offenses."[5]

The existing medical marijuana program in Massachusetts registers nonprofit organizations to cultivate and dispense marijuana as well as patients and physicians.[6] As of January 2018, the program had 227 registered certifying health care providers and nearly 50,000 active patients. The program has consistently added roughly 2,000 patients per month over its history. There are 22 registered marijuana dispensaries with final certification and approval to sell, 6 with final certification but not yet approved to

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[1] https://www.mass.gov/lists/medical-use-of-marijuana-program-monthly-dashboards.

[2] Mass. Session Laws ch. 351, § 18 (2016).

[3] Mass. Gen. Laws ch. 94G, § 14.

[4] Mass. Session Laws ch. 55, § 12 (2017).

[5] Mass. Gen. Laws ch. 94G, § 14.

[6] https://www.mass.gov/medical-use-of-marijuana-program.

sell, and 99 with provisional certificates and in the inspection phase. In contrast to the adult use program, the medical program requires those selling medical marijuana to follow a seed-to-sale model—that is, the same entity is responsible for the product from cultivation to sale in licensed dispensaries. In addition, the marijuana is not subject to any taxes, and only nonprofit organizations can participate.

To implement and administer the adult use program and create a safely regulated industry, the state formed the Cannabis Control Commission (CCC) in 2017. The CCC will also take over regulatory activities for the medical marijuana program, currently administered by the MDPH Bureau of Health Care Safety and Quality.[7] Massachusetts also created the Cannabis Advisory Board, a 25-member group charged with studying and making recommendations to the CCC on the regulation and taxation of marijuana in Massachusetts.

The adult use program in Massachusetts and the study presented here have the benefit of learning from experiences in several other states that have implemented similar programs in the past four years. Colorado and Washington approved ballot measures in 2013 to legalize marijuana for adult use and began retail sales in 2014. In 2014, Alaska, Oregon, and Washington, D.C. voted to legalize adult use, with retail sales beginning in 2015 in Oregon and in 2016 in Alaska; retail sales are not yet permitted in Washington, D.C. In 2016, California, Maine, Nevada, and Massachusetts approved ballot measures, with retail sales beginning in 2017 in Nevada and 2018 in California and Massachusetts; retail sales are not yet permitted in Maine. Finally, the state legislature in Vermont legalized adult use in 2018. Although the experiences with adult use of marijuana in these states have been brief, the states consistently saw substantial increases in revenue collected from retail sales after the first year. Revenue collected in the first year ranged from $1.7 million in Alaska to $67.6 million in Colorado.[8] There were substantial increases in the second and third years of the programs; for example, the revenue collected by the Washington Liquor Cannabis Board (LCB) increased from $64.9 million in the first year of the program to $314.8 million in the third year (Washington State LCB, n.d.). In addition, the revenue collected was substantially above the amount projected by the states prior to implementation. Finally, there is some limited evidence suggesting that marijuana legalization could have positive impacts on public health and safety outcomes and criminal justice costs and outcomes (such as reduced incarcerations); however, the evidence is primarily for impacts from medical marijuana legalization, little evidence establishes causal links between legalization and the outcomes, and the timeline for observing impacts for legalization is brief (four years at most for the earliest implementers).

There are a handful of differences between the planned program in Massachusetts and other states that will likely affect the implementation and impact of legalization. First,

[7] https://mass-cannabis-control.com/about-us-2/.

[8] Alaska: http://tax.alaska.gov/programs/programs/reports/monthly/Marijuana.aspx?ReportDate=8/1/2017; Colorado: https://www.colorado.gov/pacific/revenue/colorado-marijuana-tax-data; for a summary of revenue collected, see http://www.drugpolicy.org/legalization-status-report.

other states have implemented substantially higher tax rates than the planned 17% tax rate in Massachusetts (excluding the local tax rate), which influences the price of marijuana in the licit market and thus how much demand is met by retail sales versus the black market. In high-tax Washington (44% point-of-sale tax, excluding the local tax rate), despite the fact that the licit price of marijuana has dropped over time and is only slightly above black market prices, licensed sales account for only about 30% of demand; the rest is met by the state's loosely regulated medical marijuana market and other black market sources.[9] By contrast, in Colorado, where marijuana taxes were lower (27.9% combined tax rate through July 2017, excluding the local tax rate), an estimated 70% of demand is met by the licit market, with much of the remaining demand met by legal home-grown product. Differences in the structure of the medical marijuana programs will also influence the impact of legalization. The cultivation and sale of medical marijuana is strictly regulated and less accessible to Massachusetts residents compared to other states. Out of 27 states with medical marijuana programs, Massachusetts ranks 15th highest in terms of the number of medical marijuana patients per 1,000 state residents (Marijuana Policy Project, 2018); programs in California, Colorado, and Oregon include a much greater proportion of residents.[10] On the other hand, other states apply taxes to medical marijuana sales to varying degrees; the fact that the Massachusetts medical marijuana program is untaxed could make it more attractive to marijuana consumers once retail sales begin.

In this study, we combine evidence from implementation in other states with the details and nuances of Massachusetts programs and residents to estimate fiscal impacts of legalizing adult use of marijuana on state and local budgets. We estimate impacts separately for key domains of interest: (1) sales and business tax revenue from retail marijuana sales, (2) law enforcement costs, (3) the costs of regulatory oversight, and (4) estimated impacts on state public health expenditures and individual income tax revenue as a result of changes in worker productivity (both of which were included in a supplemental model). Our estimates reflect impacts expected only within the first two years after retail sales are allowed but also include start-up costs and revenue. Given the uncertainty of many of the inputs used to estimate impacts in some of these domains (for example, the projected price of marijuana in the retail market or the percentage of current users that will purchase their marijuana in the licit market), we conducted a number of sensitivity analyses to test the robustness of the results to our inputs. The results generated in the study will help the state and municipalities plan for the impacts of legalization while also providing a point of comparison for early impacts once the program is implemented. Furthermore, the study will provide valuable information to other states considering legalization on the complex public health, public safety, and economic impacts of legalizing marijuana.

[9] http://www.denverpost.com/2016/01/06/washington-state-marijuana-retailers-cope-with-falling-pot-prices/ and https://www.economist.com/news/briefing/21692873-growing-number-countries-are-deciding-ditch-prohibition-what-comes.

[10] https://medicalmarijuana.procon.org/view.resource.php?resourceID=005889.

Methods

Data Sources

We developed a model to estimate changes expected in four key domains within the first two years of retail sales. Each domain (for example, marijuana sales tax revenue) included individual measures (for example, marijuana use prevalence and the price of marijuana) that we estimated using three main sources of information: existing literature, interviews with academic and government experts, and secondary data sources. For each measure that fed into the model, we defined a range of plausible values as follows:

- If multiple (high quality, rigorous) studies or sources estimated the same metric, we defined the range based on the point estimates from these sources.
- If only a single study was used to estimate a metric, we defined the range based on the confidence interval around the point estimate from that paper.
- If there was no credible study or source for a given metric, we estimated a range using information from other states with legalized adult use or from expert stakeholder input.

Literature Review

To inform estimates of the impact of legalization in Massachusetts, we first reviewed the literature on the impacts of marijuana laws or policies on consumption of marijuana, alcohol, and tobacco; public health; public safety; and worker productivity. We also used the literature to identify major sources of direct costs and revenue stemming from marijuana legalization, plus demographic subgroups that are affected differentially by legalization. As a starting point, we first searched peer-reviewed publications based on key search terms (such as “marijuana” and “legalization”) applied to the MEDLINE®, Scopus, and EconLit databases. To avoid excluding potentially relevant search results, we used a broad set of search terms related to marijuana legalization rather than searching by specific terms related to consumption, public health, public safety, and labor productivity. We then searched the gray literature to identify working papers from the National Bureau of Economic Research, research briefs, and other reports published from policy institutes and state governments. After excluding papers based on a review of titles, we reviewed the abstracts to ascertain relevance. We identified 57 candidate papers, to which we uniformly applied a set of causal evidence criteria, as described below, to determine inclusion.

Because the literature has focused mostly on medical marijuana legalization, and there is limited literature on adult use legalization, many of the model impacts derived from the literature are based on the experiences of medical marijuana programs. To account for the possibility that these impacts will not accurately reflect the experience of legalization in Massachusetts, we incorporate ranges for estimates derived from this literature, along with a sensitivity analysis that removes all impacts taken from the medical marijuana literature.

Causal Criteria

To ensure that our model estimates are based only on papers that demonstrate strong causal evidence that links outcomes directly to marijuana policies, we developed a set of guidelines to determine inclusion of impacts in our model estimates.[11] We rated each paper based on the strength of evidence as high, moderate, or low causal evidence for marijuana-attributable impacts. A high rating indicates that the analysis meets high methodological standards (for example, with a control group included in the analysis) and the impacts estimated are credible; it does not mean that the study found positive impacts. A moderate causal evidence rating means that we are somewhat confident that the estimated impacts are attributable to the intervention studied, but other factors that were not included in the analysis could have contributed to the impacts observed. Research not meeting the criteria for a high or moderate causal evidence rating received a low causal evidence rating, indicating that we could not be certain that the impacts observed were attributable to the marijuana law or policy being studied. To derive estimates for our model measures, we relied only on studies with a high causal rating. Of the 57 candidate papers reviewed, 16 met the criteria for high causal evidence. As our research progressed, we identified an additional 3 papers published in 2017 that had high causal evidence, resulting in a total of 19 (out of 60) that met our criteria for high quality evidence of impacts attributed to marijuana.
An implication of applying these strict causal guidelines to our inclusion criteria is that we ultimately excluded some studies and state government reports that used longitudinal data to examine how public health and safety outcomes (such as emergency room visits, suicides, and non-fatal crashes) changed after adult use of marijuana was legalized because these analyses lacked valid comparison groups. Our exclusion of these studies does not imply that the results are not valid or useful for certain purposes, but rather that we cannot be confident that the pre-post changes are attributable to legalization.

Stakeholder Interviews

For certain domains of interest, there was insufficient rigorous evidence from the literature on causal impacts of legalization to inform our model estimates. Instead, we gathered information from interviews with expert stakeholders in Massachusetts and other states with legalized marijuana retail sales as well as from researchers studying marijuana legalization. We also used these interviews to gain insight into contextual differences between Massachusetts and other states with legalized adult use that may affect our modeling approach or interpretation of estimates. We interviewed experts in the following knowledge areas: (1) regulatory costs to state and local governments, (2) regulation of the current Massachusetts medical marijuana program, (3) the degree of shift from illicit to legal consumption, (4) current law enforcement practices in Massachusetts, and (5) public health experiences and budget expenditures in Colorado. For each interview, we developed separate protocols with tailored questions that we

[11] These guidelines follow the Clearinghouse for Labor Evaluation and Research (CLEAR). CLEAR was established by the Department of Labor to promote informed decision making and policy development by providing a central and trusted source of research evidence.

asked in person, by phone, or through email correspondences. Our notes from these interviews informed the model estimates for measures and domains of interest, as detailed in Table 1.

Table 1. Model Measures Informed by Stakeholder Interviews

Domain	Interviewee's institution	Model measure informed by interview
Tax revenue	Harvard University	Percentage shift from illicit to legal market for current adult users Percentage change over time in current prices of marijuana
Regulatory oversight	Washington State Institute for Public Policy (WSIPP)	State regulation costs State regulation revenue
	MDPH	Number of infractions per RMD per year
Law enforcement	Massachusetts Executive Office of Public Safety and Security (EOPSS)	Number of misdemeanor arrests Number of misdemeanor convictions Number of incarcerations Number of inmates on supervised release (parolees/probationers) Percentage change in misdemeanor arrests Percentage change in misdemeanor convictions Percentage change in incarcerations Percentage change in supervised release Costs of employee training on cannabis impaired driving
Public health and safety	Colorado Department of Public of Health	Suicide estimates (used in supplementary analyses) Marijuana Tax Cash Fund expenditures
	Massachusetts Bureau of Substance Abuse Services	Cost associated with substance use disorder treatment

MDPH = Massachusetts Department of Public Health; RMD = registered marijuana dispensary.

Secondary Data Sources

We augmented information from the literature and key informant interviews with analyses of a number of secondary data sources. To estimate taxable sales from marijuana, we required information on marijuana pricing. We extracted this information from three websites that aggregate crowd-sourced information on marijuana pricing (as of December 2017): Budzu and PriceofWeed (which enables users to submit information on the location where they purchased marijuana and on the price, amount, and quality of the marijuana purchased) and a document hosted on Google Sheets called Dispensary Sheet (which displays information about the price of marijuana for each amount sold at Massachusetts dispensaries). Because retail marijuana sales are not yet legal, information on the current price per gram of dried flower marijuana from these sites may contain a combination of prices in the illicit market and those in the medical market. We also used data supplied by MDPH to identify the median price of medical marijuana sold in registered marijuana dispensaries (RMDs) in Massachusetts (see Appendix D).

We obtained data on the prevalence of current marijuana use from a combination of the MBHS Task 1 survey of the general population in Massachusetts; the 2015 National Survey on Drug Use and Health (NSDUH, based on national estimates because Massachusetts-specific detailed data were unavailable at the time of the analysis[12]); and the 2015 Behavioral Risk Factor Surveillance System (BRFSS) of Massachusetts residents.[13,14] For adolescent marijuana use prevalence, we obtained estimates from the 2015 Massachusetts Youth Risk Behavior Surveillance System (YRBSS) survey of 9th through 12th grade students,[15] the 2015 Massachusetts Youth Health Survey (YHS) of middle and high school students,[16] and 2015–2016 NSDUH estimates.[17]

We gathered estimates of changes in regulatory costs and revenue attributable to retail legalization from CCC, MDPH, Washington, and Colorado budgets. Given that the CCC is expected to take over regulatory oversight of the medical marijuana program from MDPH, the increase in start-up costs for Massachusetts fiscal year (FY) 2018 were based on the difference between the CCC budget estimate[18] and projected FY 2017 costs from the MDPH's Medical Marijuana Trust Fund Annual Report.[19] Thereafter, for FY 2019 and FY 2020, we inflated CCC and MDPH projections of costs to account for the expected growth in the number of RMDs in operation (estimated to be 26 by the end of FY 2018, 40 by the end of FY 2019, and 123 by the end of FY 2020, based on data posted by MDPH on the current status of all registered marijuana dispensaries and applications through January 12, 2018[20]). We also translated recurring marijuana-related law enforcement costs incurred in Washington (based on the I-502 Fiscal Impact Statement[21]) and public safety costs incurred in Colorado[22] to Massachusetts' projected costs on a per capita basis.

Sources of regulatory revenue within the first two years of legalization include marijuana dispensary application fees and fines collected for infractions or deficiencies. To

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[12] https://www.samhsa.gov/samhsa-data-outcomes-quality/major-data-collections/reports-detailed-tables-2015-NSDUH.

[13] https://www.cdc.gov/brfss/annual_data/annual_2015.html.

[14] We defined respondents who indicated past-month or past-30 day marijuana use as current users. We chose past-month use because it was the most contemporary use option available, and because we identified only minor differences (less than 5%) between past-month and past-year users in 90% of records.

[15] https://nccd.cdc.gov/youthonline/App/Results.aspx?LID=MA.

[16] https://www.mass.gov/files/documents/2016/09/vp/youth-health-risk-report-2015.pdf.

[17] https://www.samhsa.gov/data/sites/default/files/NSDUHsaePercents2016/NSDUHsaePercents2016.pdf.

[18] https://www.mass.gov/files/documents/2017/11/08/CNB_Budget_Request_FINAL.pdf.

[19] https://www.mass.gov/files/documents/2017/03/zs/mmj-annual-trust-fund-report-2017.pdf.

[20] https://www.mass.gov/service-details/massachusetts-medical-use-of-marijuana-program-snapshot.

[21] http://www.vote.wa.gov/guides/2012/I-502-Fiscal-Impact.html.

[22] https://drive.google.com/file/d/0B0TNL0CtD9wXdjFWWUhIMm5TMjQ/view.

estimate regulatory revenue, we inflated FY 2017 projections from MDPH's Medical Marijuana Trust Fund Annual Report, as described above for the start-up costs, to reflect the growth in RMDs. We also included estimated fines that the CCC will collect for infractions in FY 2019 and FY 2020. Though CCC fines can be as high as $25,000 per deficiency, we assumed an average fine of $1,000 (in line with Group 2 regulatory marijuana fines in Washington[23]) and assumed five deficiencies per RMD per year (based on conversations with MDPH). We did not factor in additional licensing revenue because, based on our analysis of data from MDPH on the current status of all registered marijuana dispensaries and applications through January 12, 2018, we do not expect to see a substantial increase in the number of RMD applications in the two-year study period compared to current application rates.

Finally, several secondary data sources informed our estimates of public health effects of adult use legalization: treatment admission data from the 2011 and 2016 Massachusetts Treatment Episode Data Set (TEDS)[24] and the Massachusetts Budget and Policy Center, data on suicides from the 2015 Centers for Disease Control and Prevention National Vital Statistics System statistics on Massachusetts, traffic fatality statistics from the 2015 Fatality Analysis Reporting System (which were compiled by the MBHS Task 2 team), and 2016 data on the number of opioid-related deaths from MDPH.

To translate estimates from other states to Massachusetts, we used data from the U.S. Census microdata (Ruggles, Genadek, Goeken, Grover, & Sobek, 2017) and the 2015 American Community Survey 5-Year Estimates (United States Census Bureau, 2015) on Massachusetts population size and demographics.

MBHS Task 1 Survey

We analyzed data from the Massachusetts general population adult survey, administered as part of MBHS Task 1 by the University of Massachusetts' Donahue Institute, to obtain estimates of the prevalence of marijuana use, the number of regular versus heavy users of marijuana, and use by mode of consumption. All estimates were based on weighted frequencies that were generated using SAS PROC SURVEYSELECT (SAS version 9.4).

Our estimate of prevalence of current marijuana use came from a question on use of marijuana or hashish at least once within the past 30 days. We calculated the prevalence of use statewide (based on all individuals surveyed) and combined this information with data on the prevalence of use obtained from the NSDUH and BRFSS surveys to obtain a range of plausible values that fed into our models. We also estimated the number of regular versus heavy users of marijuana in Massachusetts based on definitions in the literature that rely on the number of days of marijuana use in

[23] http://apps.leg.wa.gov/wac/default.aspx?cite=314-55-525.

[24] https://www.samhsa.gov/data/sites/default/files/TEDS2011St_Web/TEDS2011St_Web/TEDS2011St_Web.pdf (Tables 2.1 and 2.2) and https://wwwdasis.samhsa.gov/webt/quicklink/MA16.htm.

the past month (Kilmer et al., 2013). We calculated the number of individuals surveyed who used marijuana between 1 and 20 days in the past month (defined as regular users) and how many used marijuana 21 days or more in the past month (defined as heavy users). Finally, we examined modes of consumption and found that the clear majority of users (95%) consume marijuana as a dried flower product (by smoking or vaporization)—either alone or in combination with other modes of consumption (such as by eating it, dabbing it, or applying it topically or sublingually). We therefore based our pricing of marijuana on price per gram of dried flower product.

In addition, we estimated prevalence of marijuana use at the city or town level using data collected in the MBHS Task 1 survey by respondents' five-digit ZIP code. Because ZIP codes tend to span multiple cities, we used a two-part approach to allocate respondents to a single city or town, based on MassGIS data on city and town boundaries:[25] (1) we associated each ZIP code to the city or town that contained the majority of the ZIP code boundary, and (2) if no city contained the majority of the ZIP code boundary, we used the town or city that contained the geographic center of the ZIP code. We then calculated the prevalence of current marijuana use in each city or town for cities and towns with at least 15 MBHS Task 1 survey respondents (to ensure we had sufficient data to produce a valid estimate); for the remaining municipalities, we estimated the prevalence by averaging the current marijuana use prevalence estimates from the national NSDUH and Massachusetts-specific BRFSS surveys.

Statistical Modeling

Our model estimates the fiscal impacts of shifting from a medical marijuana to a broader adult use program within the first two years after retail sales begin. We also include start-up costs and revenue. Our modeling consists of three models:

(1) A *main* model, which includes primary measures that we hypothesize are major drivers of economic impacts to the state and for which there is strong evidence to inform estimates: sales tax revenue, regulatory oversight costs and revenue, and reductions in marijuana-related law enforcement activities
(2) A *supplemental* model, which adds secondary impacts on public health, public safety, and income tax revenue for which the evidence is less definitive or immediate than those domains included in the main model
(3) A *local* model, which estimates local tax revenue for each city or town in Massachusetts (assuming the maximum local tax rate of 3%)

We first calculated measure-specific revenue or savings and measure-specific costs or losses by multiplying various input estimates (for example, to calculate marijuana sales revenue, we multiplied the estimated number of marijuana users by the average grams of marijuana used per day by the average price per gram of marijuana). To do so, we combined information on pre-legalization baseline measures (such as the number of marijuana users) with estimates of the post-legalization change (such as the percentage

[25] https://docs.digital.mass.gov/dataset/massgis-data/zip-codes-5-digit-here0navteq-0.

change in the number of marijuana users). We next estimated the precision of our post-legalization estimates, and finally tested the sensitivity of the findings to key assumptions. To calculate the post-legalization fiscal impact of marijuana legalization for metrics in our model, we defined a range of plausible values using information from the literature, stakeholder interviews, secondary data sources, and the MBHS Task 1 survey. We then used Monte Carlo simulation—a method that is useful when there is inherent uncertainty about model inputs—to randomly draw a value from the range for each metric and then use that value to calculate the overall impact estimate. This process of randomly drawing values from the range was repeated 1,000 times, each time resulting in a different value, to generate a probability distribution of values for the impact metric. This simulated distribution was then used to calculate a 95% confidence interval—a low and high range that indicates precision—around the impact estimate. To obtain an overall impact estimate of adult use legalization, we summed together measure-specific (for example, sales tax revenue from marijuana purchases by adults considered heavy users, adults considered regular users, and adolescents) for each domain included in the model.[26] In Table 2, we summarize baseline and projected values for each input in our models (see Appendix C Table C.1 for detailed information on the variables and data sources used to construct each measure). In the Limitations section, we indicate the measures we excluded from our model because we lacked sufficient data or causal evidence for their inclusion.

[26] Because we produce a distribution of outcome values for each level of impact (measure, domain, and model), the average value for a summed outcome will not exactly equal the sum of the average components that fed into it (for example, the sum of the individual measures used to calculate sales tax revenue does not exactly equal the total impact of the sales tax revenue domain); however, we the differences are small.

Table 2. Main and Supplemental Model Input Values

Measure	Baseline	Projected	Difference	(%)
Main model				
Domain: Sales and business tax revenue				
Sales tax revenue from marijuana purchases				
Number of adolescent users age 17 or younger	158,892	158,616	-276	(-0.2%)
Number of regular users age 18 or older[a]	318,797	394,896	76,099	(23.9%)
Number of heavy users age 18 or older[a]	150,436	150,436	0	(0%)
Sales tax revenue from beer	$72,830,435	$69,271,226	-$3,559,209	(-4.9%)
Business income tax revenue from dispensaries	0	$40,501,857	$40,501,857	(n.a.)
Domain: Regulatory oversight				
Costs over two years	$41,927,099	$43,706,042	$1,778,944	(4.2%)
Revenue over two years	$112,728,599	$114,914,006	$2,185,407	(1.9%)
Domain: Law enforcement				
Marijuana related				
Arrests	240	84	-156	(-65%)
Convictions	159	57	-102	(-63.9%)
Incarcerations	40	14	-26	(-65%)
Parolees and probationers	122	43	-79	(-64.8%)
Averted mortality due to traffic fatalities[b]	306	274	-32	(-10.6%)
Employee training on cannabis impaired driving	$0	$655,000	$655,000	(n.a.)
Supplemental model				
Domain: Public health				
MassHealth prescription drug expenditures	$459,769,135	$452,684,073	-$7,085,063	(-1.5%)
Substance abuse treatment admissions				
Cannabis	2,840	3,387	547	(19.2%)
Opioid	3,956	3,498	-458	(-11.6%)
Averted mortality[b]				
Opioid-related deaths	1,990	1,633	-357	(-17.9%)
Suicides, males age 20-29	76	67	-9	(-11.2%)
Suicides, males age 30-39	77	68	-9	(-11.2%)
Worker productivity				
Full-time equivalent dispensary jobs	110	617	507	(461.0%)
Hourly earnings, males age 20-29	$15.60	$15.21	0	(-2.5%)
Females age 50+ with a qualifying medical marijuana condition, employed full time	90,584	99,093	8,509	(9.4%)
Males age 50+ with a qualifying medical marijuana condition, hours worked/week	41.7	43.8	2	(5%)

Sources: Mathematica's analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimates.

Note: Baseline values are for Massachusetts fiscal year 2018 (before retail sales begin), while projected value are for fiscal year 2020 (the second year of retail sales).
[a] Regular users are those who consume marijuana between 1 and 20 days per month; heavy users are those who consume marijuana 21 or more days per month (Kilmer et al., 2013).

[b] These numbers are also used to estimate income tax revenue from averted mortality in the supplemental model.
n.a. = not applicable.

Sensitivity Analyses for State-Level Models

We conducted two analyses to examine the sensitivity of our results. The first involves the number of current marijuana users in Massachusetts. In our primary analysis, we used the NSDUH and BRFSS population surveys to establish a range (8.6% to 12.1%) for the prevalence of current marijuana use in Massachusetts. In a sensitivity analysis, we expanded the high end of the range to 20.1%, based on the MBHS Task 1 survey estimate. It is unclear why the estimate of use prevalence was substantially higher in the MBHS Task 1 survey than in existing population surveys. On the one hand, because the NSDUH and BRFSS surveys were conducted prior to adult use legalization, they may have underreported marijuana use, which is a recognized problem in surveys targeting illegal substance use (Harrison, Martin, Enev, & Harrington, 2007). Because the MBHS Task 1 survey was conducted after the referendum to legalize retail marijuana was passed in Massachusetts, it may have captured more honest reporting that captures true Massachusetts-specific consumption patterns. However, it should be noted that the rate of consumption reported in Colorado in the 2014–2015 NSDUH—which was conducted after legalization—was still only 17%. On the other hand, because the MBHS Task 1 survey response rate was low (roughly 20% of individuals who were mailed a survey completed the survey), it is not clear how representative MBHS Task 1 survey estimates are of the general adult population in Massachusetts and whether self-reporting bias affected the estimates obtained. In our sensitivity check, we examined what effect using the MBHS Task 1 survey consumption estimate as the high end of the range had on our overall impact estimate.

In our second sensitivity analysis, we set all impacts based on the medical marijuana literature to zero, given the possibility that these impacts might have already been realized when Massachusetts implemented the medical marijuana program. In our primary analysis, we assume that the expansion from the medical marijuana to the adult use of marijuana regime will generate similar impacts as the expansion from no legalization to the medical marijuana regime. However, while far from conclusive, the limited evidence of the impacts from the expansion from medical to retail legalization are small or statistically insignificant (Dills, Goffard, & Miron, 2016, 2017). In this sensitivity analysis, we take the conservative view that there are no behavioral impacts generated from the shift from the medical to adult use regimes beyond consumers switching from the black market to legal retail market. In other words, we do not anticipate any impacts of adult use legalization on the likelihood or frequency of marijuana consumption, nor do we anticipate any impacts on public health outcomes explored in the supplemental model, such as alcohol or opioid consumption, or economic impacts from increased labor force participation of older adults. The results from this sensitivity analysis can therefore serve as a lower bound of the expected fiscal impact of marijuana legalization in Massachusetts.

Local Analyses

To estimate fiscal impacts to local governments, we projected the revenue that cities and towns would collect from local taxes imposed on retail marijuana sales during the

first two years of adult use legalization. Unlike our main model, the local model does not factor in costs associated with adult use legalization (such as increased training and law enforcement costs that are anticipated at the local level) because of the high level of uncertainty associated with these costs, coupled with a lack of local-level data to inform such estimates. To estimate revenue, we assumed a local tax rate of 3% (the maximum local tax) in all cities and towns with an RMD expected to open within the first two years of retail marijuana sales. We applied this rate to the projected number of marijuana purchases, calculated using the prevalence of current marijuana use assumed in our state-level models (defined to range from 8.6% to 12.1%, based on the NSDUH and BRFSS surveys), which was assumed to be consistent across all cities and towns. In a sensitivity analysis, we used local-level prevalence estimates that were informed by the MBHS Task 1 survey for cities and towns with at least 15 individuals surveyed.
We assumed that marijuana users in cities and towns without a projected RMD would purchase marijuana from the nearest city or town with an RMD. Based on the locations of RMDs expected to open within the two-year study period, we expect that individuals in the majority of cities and towns (n = 337) will reside within 10 miles of an open RMD and that all individuals in Massachusetts will reside within 20 miles of an RMD. Finally, in the primary local analysis, we assumed that 50% to 80% of marijuana users would shift from purchasing their marijuana in the illicit market to purchasing from RMDs, based on information from the Washington State Institute of Public Policy (WSIPP) and a stakeholder interview. In a sensitivity analyses, we set the shift to 50% and 80% to examine the effect on the results.

Results

Main Model Impacts

Our main model included changes in the following primary measures: sales tax revenue (from marijuana purchases among adults with regular and heavy use and among adolescents using marijuana purchased from RMDs); business income tax revenue from RMDs (which we estimated by applying an 8% business tax rate to our estimate of gross revenue, excluding business-related expenses); regulatory costs and revenue; and marijuana-related law enforcement activities (related to decreases in arrests, convictions, incarcerations, and parolees/probationers). Based on our main model, we estimate that marijuana legalization will result in a net two-year fiscal contribution of \$215.8 million (Figure 1 and Table 3). The majority of this gain (70%, amounting to \$150.3 million) will come from sales tax revenue, followed by RMD business tax revenue (28%, amounting to \$60.1 million); about 2% will come from savings due to reduced law enforcement needs to police illegal marijuana use; and less than 1% will come from regulatory revenue—largely because we estimate that Massachusetts will spend about the same amount to regulate marijuana sales and production (\$1.8 million) as it will receive in application fees and violation fines from marijuana dispensaries (\$2.2 million). Based on the probability distribution generate from the Monte Carlo simulation, we estimate a 95% confidence interval of \$95.7 to \$405.9 million around our main model impact estimate.

Sales tax revenue was driven largely by marijuana purchases anticipated by adults categorized as heavy users (we estimate these consumers are responsible for $89.8 million of the $150.3 million expected in new sales tax revenue). Additional sales tax revenue comes from: adults categorized as regular marijuana users ($23.3 million); adolescents who consume marijuana that was purchased by adults from RMDs ($14.6 million); tourist purchases ($14.4 million), which we assumed would comprise between 7% and 12% of total tax revenue, based on estimates from Light et al. (2016) and Cooper et al. (2016); and new adult users ($7.7 million), whose use of marijuana begins after the commencement of retail sales. As a result of retail marijuana sales, we also forecast a $3.6 million reduction in sales tax revenue from beer sales over the study period. The majority of law enforcement savings are realized through reductions in law enforcement costs related to vehicular crashes that result in fatalities ($3.8 million) and in the number of marijuana-related incarcerations ($1.4 million).

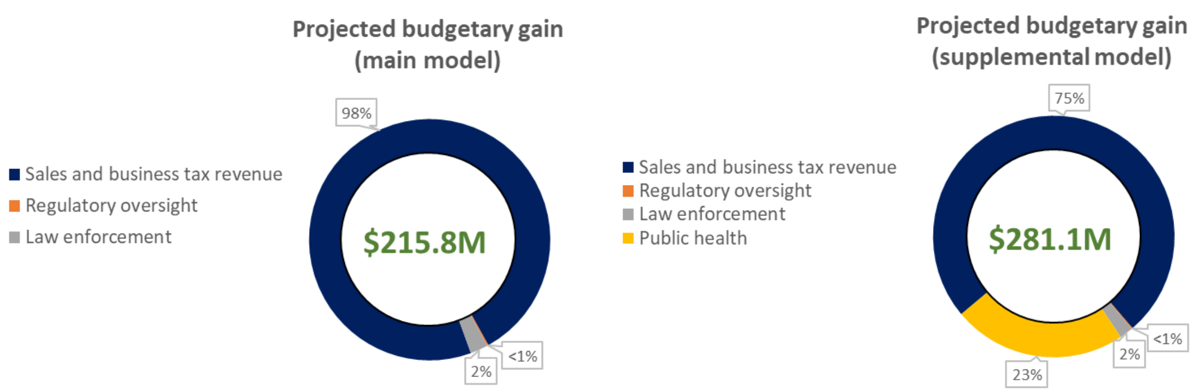
Supplemental Model Impacts

Our supplemental model included changes in the following health-related measures estimated with less certainty: income tax revenue (mainly as a result of increases in worker productivity among adults age 50 or over, coupled with extra years of life due to averted mortality), decreased MassHealth spending on prescription drugs replaced with marijuana, decreased spending on opioid addiction treatment, increased spending on cannabis addiction treatment, and state-level savings due to averted deaths. With respect to averted deaths, the evidence from the medical marijuana literature suggests a decrease in traffic fatalities (Anderson, Hansen, & Rees, 2013; Santaella-Tenorio, Mauro, Wall, Kim, & Martins, 2017), which would decrease legal costs to the state, along with a decrease in suicides among males ages 20 to 39 (Anderson, Rees, & Sabia, 2014), which would decrease state spending on related medical costs.
Adding these measures to our main model increased our projected budgetary gain by $65.3 million, and yielded a total impact estimate of $281.1 million (Table 3). Across all domains, estimated changes in sales and business tax revenue represent approximately 75% of all economic and fiscal impacts, while revenue and savings as a result of public health effects account for an additional 23%; regulatory oversight and law enforcement fiscal impacts together constitute less than 5% of estimated impacts. The 95% confidence interval around the secondary model impact estimate was $98.4 million to $528.3 million.

When we examine projected revenue or savings (without factoring in projected costs or losses), the single largest contributor is sales tax revenue for marijuana purchases at RMDs by heavy adult users, followed by marijuana-related business income tax revenue (Appendix C Figure C.1). We also estimate substantial income tax revenue from gains in worker productivity ($54.4 million). In particular, we project growth in hours worked among men over age 50 ($46.7 million) and in full-time employment among women over age 50 ($20.9 million) who have a debilitating medical condition (such as chronic back pain or depression) that is well-controlled with marijuana. Retail marijuana legalization is estimated to reduce mortality from suicides, vehicular crashes, and opioid-related deaths; together, these could increase income tax revenue by $1.1 million and reduce state public health spending by $0.7 million.

When we look at costs or losses (data not shown), we project that a reduction in average hourly earnings as a result of marijuana addiction or dependence will reduce state income tax revenue by $12.5 million. We also estimate a loss of $3.6 million in alcohol sales taxes because of substitution effects (whereby individuals purchase marijuana in lieu of alcohol). The estimated impact on state spending for substance abuse treatment is minimal, composed of reduced spending on opioid addiction treatment ($1.0 million) that is offset by increased spending on cannabis addiction treatment ($1.1 million).

Figure 1. Estimated Two-Year Impacts of Legalizing Adult Use of Marijuana



Sources: Mathematica's analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimates.

Note: Each model sums the estimated changes in revenue or savings and the estimated costs or losses associated with the domains in the legend. Changes were projected within the first two years of retail sales, and include start-up costs associated with migrating from a medical marijuana program to a broader adult use marijuana program. Percentages sum to more than 100% due to rounding.

Table 3. Estimated Two-Year Impacts by Model and Domain

Model	Estimated net gain in revenue	Range (95% confidence interval)
Main model	**$215,750,686**	$95,740,066 –
Sales and business tax	$210,431,454	
Sales tax revenue	$150,308,182	
Business income tax	$60,123,273	
Law enforcement	$5,055,969	
Regulatory oversight	$406,463	
Supplemental model	**$281,054,592**	$98,400,908 –
Public health	**$65,303,906**	$2,660,843 – $122,382,655
Individual income tax	$57,400,988	
State spending on	$7,764,492	

Sources: Mathematica's analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimates.

Note: The sum across domains may not equal the overall estimate because of random variation in the simulations. The range is based on the 95% confidence interval around the model estimate.

Sensitivity of Impacts

In our first sensitivity analysis, in which we increased the upper end of the range of plausible values for prevalence of current marijuana use to include the MBHS Task 1 survey estimate, our main model impact estimate increased by 38% (from $215.8 million to $298.8 million), and our supplemental model estimate increased by 29% (from $281.1 million to $364.1 million). In our second sensitivity analysis, in which we adjusted all impacts derived from the medical marijuana literature to zero, our main model estimate decreased by only 8% (to $143.9 million), but our supplemental model estimate (which included a number of public health measures informed by the medical marijuana literature) decreased by 28% (to $201.4 million).

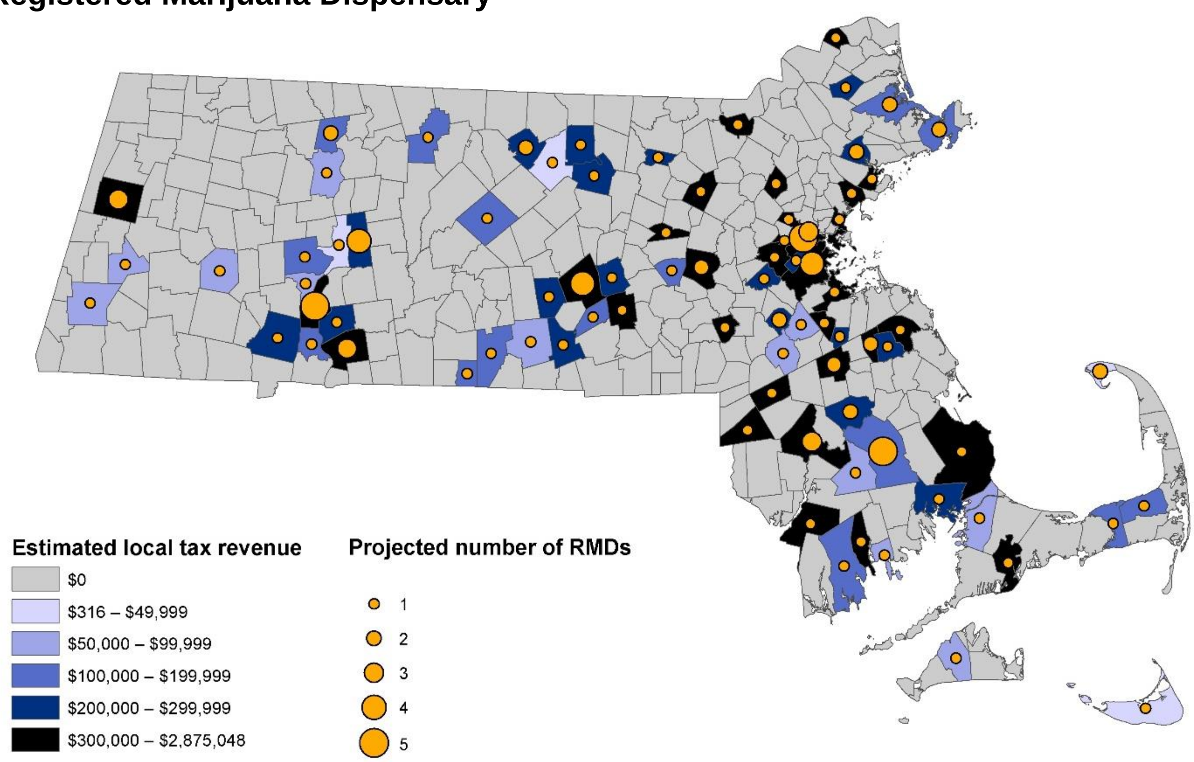
Local Impacts

In Figure 2, we show our estimated two-year local tax revenue, assuming a 3% local tax rate, along with information on the projected number of RMDs expected per city or town. With some exceptions, local tax revenue is generally higher on the coast and lower in the western part of the state. In Table 4, we summarize estimated local tax revenue by city or town density, defined using the methodology of Pozzi and Small (2005) as rural (≤ 100 people/km^2); suburban low, medium, and high density (100–500 people/km^2, 500–1,000 people/km^2, and 1,000–10,000 people/km^2, respectively); and urban (> 10,000 people/km^2). As expected, revenue is highest in dense regions, though there is considerable fluctuation in tax revenue projections among the 51 high-density suburban cities and towns (see Appendix C Table C.3 for detailed results). Both sets of results are restricted to the 83 cities and towns in which an RMD is expected to be open within the first two years of retail marijuana sales.

In Appendix C Figure C.2, Table C.2, and Table C.3, we show how local revenue estimates would change if RMDs were open in all cities and towns across Massachusetts, such that marijuana users would no longer travel to nearby cities or towns to purchase marijuana. For some of the 83 cities and towns included in the primary analysis—particularly those that will be more isolated from other RMDs in the state—local tax revenue estimates dropped dramatically (for example, from about $992,000 in Burlington to about $108,000).

In the sensitivity analysis in which we used local-level marijuana use prevalence estimates that were informed by the MBHS Task 1 survey (which were available mostly for urban and high-density suburban cities and towns), our estimate of local tax revenue increased by 215% for urban cities (to almost $1.3 million) and by 20% for high-density suburban cities (to about $288,000). And in the sensitivity analysis in which we specified that the percentage shift in marijuana purchases from the illicit market to RMDs would be exactly 50% or 80% (instead of 65%, which we derived for the primary analysis based on the range of 50% to 80%), our median revenue estimates decreased and increased, respectively, by 18% for all density categories.

Figure 2. Estimated Two-Year Local Tax Revenue by City or Town with a Registered Marijuana Dispensary



Sources: Mathematica's analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimates.
Note: The figure includes estimates only for cities and towns in which a marijuana dispensary is projected to be open within the first two years of marijuana retail sales; no rural areas (< 100 people/km^2) are expected to have open dispensaries. Appendix C Table C.2 provides estimates assuming RMDs are open in all Massachusetts cities and towns within the first two years of legalization. See Appendix C Table C.3 for estimates by city or town.

Table 4. Estimated Two-Year Local Tax Revenue by Density Category

City or Town Type	Number of Cities or Towns	Two-Year Local Tax Revenue Median	Minimum	Maximum
Suburban, low density (100–500	6	$72,835	$60,801	$144,385
Suburban, medium density (501–	10	$63,272	$20,872	$170,209
Suburban, high density (1,001–10,000	51	$243,144	$68,139	$991,873
Urban (> 10,000 people/km^2)	16	$582,899	$233,498	$2,875,048

Sources: Mathematica's analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimates.
Note: The table includes only cities and towns in which a marijuana dispensary is projected to be open within the first two years of marijuana retail sales; no rural areas (< 100 people/km^2) are expected to have open dispensaries. Appendix C Table C.2 provides estimates assuming RMDs are open in all Massachusetts cities and towns within the first two years of legalization. See Appendix C Table C.3 for estimates by city or town.

Discussion

We estimate that the legalization of adult use of marijuana will result in an increase of approximately $215.8 million to the Massachusetts state budget over the first two years of retail sales, largely as a result of sales and excise taxes collected on retail marijuana purchases. Although our model includes fiscal impacts of legalization due to a number of domains, most are miniscule compared to increases expected from sales and business tax revenue. The increase will largely be a result of retail purchases made by adults with heavy use—defined as consuming marijuana an average of 21 days or more each month. New business income tax revenue from marijuana dispensaries will also be a major contributor, as will increases in income tax revenue (primarily due to increased worker productivity among adults over age 50 who are able to control debilitating medical ailments with marijuana). When we included measures calculated with less certainty (because of either a lack of data or an uncertain time frame within which impacts could occur), we estimate that the state may see an additional $65.3 million added to its budget. This increase would mainly come from added individual income tax revenue from worker productivity gains in older adults able to control serious ailments with marijuana.

Our estimate of tax revenue is heavily influenced by assumptions about the number of current marijuana users in Massachusetts. Because previous population surveys (used to inform our main model estimates) yielded a lower estimate of prevalence of use than the MBHS Task 1 survey, our main model estimate may be conservative. However, because we assumed that changes seen when moving from medical marijuana sales to retail marijuana sales could be as high as moving from no legal marijuana sales to medical marijuana sales, our fiscal estimates could also be somewhat higher than may be realized.

A strength of our analytic approach is that the Monte Carlo simulation factors the uncertainty of inputs into the model estimates; that is, we were able to incorporate plausible ranges of values for inputs to not overstate their certainty. The combination of uncertain inputs leads to substantial uncertainty in the estimated impact of adult use legalization on the state budget, as indicated by the wide confidence interval around the estimate. As more studies are published on the impacts of adult use legalization, the ranges of estimates from the literature will be better defined and our impact estimates will become more precise.

The results of our model should be interpreted in the context of Massachusetts-specific information, such as the proposed regulatory framework, tax regime, and existing medical marijuana program. Below, we provide additional details on the assumptions and implications of our approach with respect to the four domains included in our analysis: sales tax revenue, regulatory oversight, law enforcement, and public health. We also compare how our estimate of the fiscal impact of adult use of marijuana legalization compares with previous impact estimates (generated from the Massachusetts Department of Revenue [DOR] and in other states with legalized use) and discuss limitations of our approach.

Sales Tax Revenue

We project fiscal impacts within a two-year window starting at the commencement of retail marijuana sales, but it is important to note that the revenue generated is heavily weighted toward the tail end of the two-year period. Indeed, in other states that have implemented retail marijuana sales for at least two years (Colorado, Washington, and Oregon), 66% to 77% of sales tax revenue collected within the first two years was generated in the second year (Colorado DOR, 2018; Oregon DOR, n.d.; Washington State LCB, n.d.), and the data suggest that sales tax revenues are likely to increase substantially after consumers, suppliers, and regulators adjust to the new regime.[27] Based on data from these states, we assumed that about 70% of the two-year estimate of sales tax revenue would be collected from Massachusetts RMDs in the second year of sales. This translates to an estimated $61.6 million collected in the first year and

[27] Alaska collected less tax revenue from legal marijuana in its second year of sales than in its first. However, Alaska differs from other states that have legalized marijuana—including Massachusetts—in many respects, including the fact that they tax marijuana by plant weight, rather than through a tax rate applied to retail sales (http://tax.alaska.gov/programs/programs/reports/Annual.aspx?60000&Year=2017). Therefore, we excluded Alaska when reviewing the experiences of states that allow marijuana sales.

$154.2 million in the second year of retail sales. It is important to note we cannot claim with certainty that spending on marijuana represents new spending rather than a shift from other recreational options like spending on alcohol. Similarly, income tax revenue from new dispensary jobs may represent transfers from other industries. As a result, it is possible that some amount of tax revenue generated by legalization may be offset by a reduction in tax revenue elsewhere.

Our methodology for estimating change in tax revenue attributable to marijuana legalization differs from other models in two major respects. First, we did not factor in changes in the price of marijuana over time because it is particularly difficult to know the rate at which prices will change within the first two years of legalization (Hunt & Pacula, 2017). Instead, we estimated a single, average price of marijuana during the study period based on crowd-sourced data and data from RMDs. We also did not link marijuana prices to sales volumes—that is, examine the price elasticity of demand—because doing so compounds this uncertainty.[28] Instead, we estimated changes in demand using marijuana use quantities derived from the literature and MBHS Task 1 survey results, coupled with changes in use behavior derived from the growing body of evidence from states that have legalized marijuana use.

Second, we did not account for expected increases in revenue related to the establishment and growth of the broader marijuana industry. Several previous studies attempted to quantify these macroeconomic impacts, with mixed results; one study concluded that previous analyses underestimate or overestimate impacts by up to 300% (Light, Orens, Rowberry, & Saloga, 2016). However, it is likely that the development of a novel industry will generate some amount of tax revenues from businesses that grow, manufacture, or test marijuana and stimulate growth among traditional businesses that supply or interact with this new market.

Our model also assumed a steady growth rate in medical marijuana patients (based on current growth trajectories) that would be unchanged after retail sales begin. Because medical marijuana is untaxed in Massachusetts, it may be more attractive to new marijuana consumers once retail sales begin. Accordingly, it is possible that the initiation of retail sales could actually increase the rate of growth in medical marijuana use. However, we did not model this scenario.

Whenever possible, we benchmarked our estimates against other sources. For example, we found that the median price per gram of dried flower marijuana ($13.70) based on crowdsourced data for Massachusetts was nearly identical to the median price per gram sold by RMDs for medical use ($13.30). Also, based on stakeholder interviews, we estimated that the price of marijuana during the two-year study period will be roughly 75% of the current price. The prices also align with data from other sources, which suggest that post-legalization prices in other states have fallen roughly 20% per year (Committee on Foreign Affairs and International Trade, 2018). Finally, data on

[28] This approach is similar to the one used by Cooper, Johnston, & Segal (2016) to model the economic impact of marijuana sales in California.

marijuana use frequency from the MBHS Task 1 survey align with data from the 2015–2016 NSDUH survey of Massachusetts residents in that both suggest that approximately two-thirds of current marijuana users are “regular” users based on their use frequency being between 1 and 20 days per month, and the remaining one-third are “heavy” users based on a use frequency of 21 or more days per month. The sources also indicate that regular users average 7 use days per month, and heavy users average approximately 29 use days per month.

Estimates of the average amount of marijuana consumed per day of use among current marijuana users were inconsistent between the MBHS Task 1 survey and the literature. To estimate dollars spent per day of marijuana use, we derived dollars spend in the past month on the average number of days marijuana was used in the past month –both of which were estimated using the MBHS Task 1 survey. We then divided this by the average price per gram of marijuana to estimate the average number of grams used per day. Our calculations yielded an average daily use of: 0.17 grams consumed by regular users and 0.32 grams consumed by heavy users. By contrast, estimates from Kilmer et al. (2013) were much higher: 0.67 grams and 1.6 grams, respectively. One explanation for the difference is that marijuana potency may have increased between 2013 and 2017, such that consuming fewer grams now achieves the same effect as in 2013. Another possibility is that our estimate of the price per gram of marijuana was inaccurate. Our estimate combines information on black market and RMD pricing. If MBHS Task 1 survey respondents paid less per gram than we estimated, this would then result in higher estimates that may be more in line with Kilmer et al. (2013). To account for the uncertainty in average marijuana grams consumed each day of use, we varied the model estimate for use between the MBHS Task 1 survey estimate and the estimate from Kilmer et al. (2013).

Regulatory Oversight

Our model suggests that within the first two years of retail sales, the cost of regulatory oversight will be offset by revenue generated from application fees and fines collected by the CCC. However, our analyses of regulatory costs incurred by other states that have legalized retail sales show a great deal of variability in the cost of regulating marijuana, even after accounting for differences in population size and number of RMDs. In Washington (which has approximately 100 marijuana dispensaries[29]), we estimated total regulatory costs to be $52,638 per dispensary per year, whereas in Colorado (which has approximately 371 marijuana dispensaries[30]), the corresponding estimate was $31,945. There are, however, notable differences in regulatory operations between states. For example, following legalization of adult use of marijuana in Washington in 2012, the state did not create a new regulatory agency but rather incorporated cannabis regulation under the state’s LCB. Given that Massachusetts will have a separate regulatory body—the CCC—rather than incorporating cannabis regulation under the state’s LCB, Massachusetts may incur additional costs not included

[29] Based on data from https://www.marijuanadoctors.com/medical-marijuana-dispensaries/WA.

[30] Based on data from https://www.colorado.gov/pacific/enforcement/med-licensed-facilities.

in the estimates from Washington. Additionally, at the time of legalizing retail marijuana, Washington did not have a robust medical marijuana law or medical dispensaries prior to the legalization of adult use of marijuana (even though medical marijuana had been legal in Washington since 1998).[31] Medical marijuana became more formally regulated in Washington in 2015, requiring a second wave of regulatory work to incorporate medical use under the LCB.

Data from Washington show that 55% of regulatory costs incurred within the first two years of legalization were associated with rulemaking, licensure, and enforcement; spending on health and social service programs accounting for another 38% of costs. In Washington, these costs totaled $105,250 per year after start-up, whereas in Colorado, the cost ranged from $164,634 to $172,031 per year. In our model, we considered as regulatory costs any recurring law enforcement activities at the state and local level, including employee blood testing for individuals suspected of driving under the influence as well as administrative, legal, and judicial costs associated with suspended or revoked licenses. We estimated these costs by translating the range of estimates from Washington and Colorado to Massachusetts on a per capita basis.

Because of a lack of data, we did not attempt to factor regulatory costs at the local level into our model. We learned through a stakeholder interview that local governments in Washington struggled to keep up with ongoing regulatory changes, which required several staff dedicated to monitoring these changes. Although local governments initially absorbed start-up costs required to regulate businesses locally, eventually the fees they collected on licenses ended up covering the costs of regulating businesses locally. Based on information from the CCC,[32] we anticipate that the Marijuana Regulation Fund that the CCC establishes could cover much of the costs of education and prevention as well as municipal police training. The expert we interviewed also indicated that the main factor differentiating local regulatory costs in Washington, from one city to another, is whether the city focuses on marijuana production or on retail sales. For producers (which are largely located in rural areas), primary costs involve odor and environmental issues surrounding waste disposal and wastewater. For retailers (which are more concentrated in urban areas), age compliance and traceability have been major sources of concern that have added costs. Also, rural towns—which were more likely to ban marijuana retail sales—incurred costs associated with lawsuits by businesses wanting to open an RMD.

Law Enforcement

Our modest projected reductions of law enforcement costs reflect a two-thirds decrease in marijuana arrests in the years preceding legalization of retail sales.[33] Because few

[31] https://www.doh.wa.gov/YouandYourFamily/Marijuana/MedicalMarijuana/LawsandRules/HistoryinWashington.

[32] https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXV/Chapter94G/Section14.

[33] According to data supplied to the authors by the Massachusetts Department of Corrections, the number of cases charged with a marijuana governing offense declined from 975 in 2010 to 336 in 2014.

people currently enter the criminal justice system for marijuana offenses, further decreases in incarcerations will have little effect on statewide expenditures. However, this estimate is subject to a few limitations. First, it is difficult to obtain reliable data on individuals charged with marijuana offenses who are also charged with other, more serious crimes. It is possible that sentence lengths assigned to this group will be reduced when marijuana sales are legally permitted, further reducing costs. Second, some law enforcement officials in Massachusetts and elsewhere are skeptical of findings that marijuana legalization reduces vehicular crashes and express concern about increases in the incidence of driving under the influence of marijuana (Migoya, 2017; stakeholder interview). If these concerns are borne out, traffic fatalities will represent an increase rather than a decrease in expenditures. Also, there may be other benefits that manifest from reducing the proportion of the population incarcerated for marijuana-related crimes. However, such benefits are challenging to quantify, given a lack of evidence, and they may take longer than two years to be realized.

With respect to impaired driving, our model included an estimated decrease in motor vehicle fatalities attributed to adult use of marijuana legalization. There is some evidence of increases in THC blood concentrations among drivers after adult use legalization that could also contribute to increases in non-fatal motor vehicle crashes. For example, a report from Washington that analyzed trends over time before and after adult use of marijuana legalization found that the proportion of drivers testing positive for THC was fairly constant before and immediately after adult use legalization took effect, but that beginning approximately 9 months after adult use legalization took effect, the proportion began to increase substantially at a rate of 9.7% per year (Tefft, Arnold, & Grabowski, 2016). In addition, the law enforcement communities in Colorado and Washington have expressed anecdotal concerns that marijuana is increasing both fatal- and non-fatal motor vehicle crashes (Migoya, 2017). Because these studies did not meet our causal evidence guidelines, we did not include estimates from them in our model.

Finally, although our model factored in a start-up cost of $655,000 in Massachusetts (based on stakeholder input) for Drug Recognition Expert and Advanced Roadside Impaired Driving Enforcement officer training, data from Washington indicate that the costs could be much higher. The Washington State Patrol spent $2.1 million on employee training on cannabis impaired driving, which accounts for 77% of the increase in law enforcement costs attributed to marijuana legalization within the first five years. Additional costs may be incurred for driving campaigns and other public safety messaging.

Public Health

Our supplemental model added projected fiscal impacts due to public health impacts of legalizing adult use of marijuana. We estimate that revenue and savings related to public health impacts will account for about 23% of the total budgetary gains projected because of legalization, based on our supplemental model. The added budgetary gain in our supplemental model mainly comes from projected increases in worker productivity (which would generate increases in individual income tax revenue) among older adults with debilitating medical conditions that are well controlled with marijuana (Nicholas & Maclean, 2016). We assumed that these productivity gains would be fully realized within the first two years of retail sales; if they span longer than two years, model estimates would need to be proportionally reduced. We also suspect that some of the productivity gains projected may have already been realized by the medical marijuana population. However, when we adjusted the population to which we applied the impact estimate (by subtracting out older medical marijuana patients, based on data from MDPH), our impact estimate decreased by only 8% for older women and 4% for older men.

Other public health savings (for example, due to reduced spending by the state on the MassHealth program to cover prescription drugs for fee-for-service beneficiaries) are expected to account for only 3% of the supplemental model estimate. Decreases in Medicaid prescription drug spending, estimated by Bradford and Bradford (2017), were based on treatment for medical conditions that medical marijuana is used to treat, including depression and psychosis. That is, we project that some individuals will use marijuana in lieu of prescription medications to treat these conditions. Because of a lack of information on how spending might change because of marijuana legalization, our model did not account for changes in spending associated with inpatient, outpatient, or emergency treatment—it was limited to prescription spending alone. It is also important to note that our model projects impacts only out to two years, and that the health effects associated with marijuana use could have a much longer latency, possibly taking decades before the full extent of benefits or harms would be seen.

Projected savings of roughly $980,000 due to decreases in opioid addiction treatment were offset by projected spending amounting to $1.1 million due to increases in cannabis addiction treatment. For both sets of costs, we focused only on the costs of treatment admissions incurred by the state. However, many individuals with drug addiction or dependence do not seek treatment; instead, costs incurred by the state government for these individuals may be related to costs associated with overdoses and emergency room visits. Because of a lack of data, we did not incorporate non-treatment costs related to addiction/dependence in our model. Likewise, when we factored in the measure related to reductions in opioid-related deaths into our model, we only accounted for increases in income tax revenue. We did not account for reductions in other costs that may be incurred for opioid-related deaths, such as the cost of ambulatory treatment (which is covered by MassHealth) or mortuary costs (which are expected to be relatively small, given a $1,500 cap on MassHealth coverage for these costs).

In our model, expected decreases in suicides among males age 20 to 39 accounted for less than 1% of expected public health savings. Although there have been anecdotal concerns that legalization of adult use of marijuana has led to an increase in suicides in Colorado and Washington, neither the literature nor state-level data we examined reflect this measure. For example, the most recent Colorado Violent Death Reporting System report noted an increase in the suicide rate in 2014 and 2015, although there were no statistically significant changes observed during this time period (Jamison, Mintz, Herndon, & Bol, 2017). Using data from this report, we calculated the change in suicide rate from the three-year period before legalization (2011–2013) to the two year-period after legalization (2014–2015) and noted a 6.25% increase in suicides over this time period. However, given that the report itself found that these changes were not statistically significant, we did not include them in our model.

Comparison with Previous Estimates

Our model included estimates of sales tax revenue as well as revenues and costs realized in other domains. Although there are no comparable estimates of projected revenues and costs related to business and income tax revenue, public health, and criminal justice costs, we discuss below the differences between our estimates of projected sales tax revenue and estimates from other states and from the DOR for Massachusetts.

Our estimate of taxable retail marijuana sales was $748.7 million ($224.6 million in the first year and $524.1 million in the second). The second year estimate amounts to $745 per adult user, which is similar to second year estimates from Oregon ($675) and Washington ($818) but is substantially lower than the second year estimate for Colorado ($1,128).[34] Differences across the states could be attributed to any or all of the following:

- *Differences in the speed at which the programs are fully implemented*. Because it takes new dispensaries one to two years to be fully operational in Massachusetts, retail marijuana sales may be limited at first, particularly in areas without RMDs. However, the fact that Massachusetts has a well-established medical marijuana program (unlike Washington at the time of retail marijuana legalization) and can learn from the experiences of other states with legalized use could hasten implementation of the adult use program.
- *Differences in tourist sales volumes*. Marijuana purchases by tourists to Colorado may have been substantially higher in the first two years of legalized adult use than they will be in Massachusetts. Colorado was the first state to implement an adult use program, and even now most of its bordering states do not have medical marijuana programs. By contrast, Massachusetts borders two other states that have legalized adult marijuana use (Vermont and Maine), and all its bordering states have medical marijuana programs.

[34] For comparability with retail sales estimates in Massachusetts and in Oregon (calculated by dividing revenue estimates from http://www.oregon.gov/DOR/programs/gov-research/Pages/research-marijuana.aspx by the 17% tax rate), we converted total sales revenue (which included medical plus retail sales) in Colorado (https://www.colorado.gov/pacific/revenue/colorado-marijuana-sales-reports) and Washington (Washington State LCB dashboard, n.d.) to retail sales revenue by subtracting the percentage of revenue due to medical sales, which we assumed would be equal to the percentage of total marijuana users (https://www.samhsa.gov/data/sites/default/files/NSDUHsaeSpecificStates2016A/NSDUHsaeSpecificStates2016.htm) that are medical users (https://www.mpp.org/issues/medical-marijuana/state-by-state-medical-marijuana-laws/medical-marijuana-patient-numbers/).

- *Differences in tax rates*. The 17% sales plus excise tax rate in Massachusetts is lower than the rate of almost 30% in Colorado, and much lower than the rate of 44% in Washington. As a result, more of the total demand in Massachusetts could be met by RMDs, as opposed to the illicit market, resulting in higher sales volumes per user compared with other states.

Our estimate of projected revenue collected through the maximum 20% tax rate in Massachusetts (assuming a maximum local tax of 3%) is substantially lower than estimates produced by the Massachusetts DOR. We estimate that the state will collect almost $105 million in tax revenue from $524 million in sales; the DOR report projects roughly $205 million in revenue from $1.1 billion in sales, after adjusting to the increase from a 12% to a 20% tax rate (Joint Committee on Marijuana Policy, 2017).[35,36] However, the difference is reduced by roughly one-third when we compare the DOR estimate to the estimate from our sensitivity analysis that uses the Task 1 survey's estimate of prevalence of current marijuana use.

The difference between our estimate and the DOR estimate is primarily due to the DOR applying per capita sales estimates from the third year of legalized use in Colorado and Washington (which saw nearly 50% and 70% increases between years two and three, respectively) to the second year of legalization in Massachusetts, believing that Massachusetts will have a shorter implementation period because the state has the benefit of learning from the experiences in Colorado and Washington. If Massachusetts second-year sales approach third-year levels from those other states, our model may underestimate this component of the fiscal impacts of legalization. However, as noted above, the speed at which dispensaries are approved to begin retail sales across the state could limit the extent to which the state is able to ramp up sales. In Massachusetts, we project that the revenue in the second year will more than double the first year's revenue. For comparison, the second year's revenue nearly doubled in Colorado and nearly tripled in Washington compared to the first year.

Limitations

Our models exclude a number of potential impacts of adult use of marijuana legalization that do not have supporting casual evidence to link the impact to marijuana laws and policies. For example, we do not have sufficient information on the impacts of legalization on a number of public health outcomes, including spending related to

[35] The Massachusetts DOR estimates $128 million of tax revenue collected on $1.07 billion in taxable sales based on a 12% total tax rate (including sales, excise, and local taxes). In a sensitivity analysis, they estimate $237 million of tax revenue collected on $1.018 billion in sales assuming a total tax rate of 23.25%. Based on these estimates, we calculate that the DOR estimate would be roughly $205 million in tax revenue with a total tax rate of 20%.

[36] The Massachusetts DOR report cites two reports with estimates that were lower than its own – a Tax Foundation Report (estimating $747 million in taxable sales based on a 15% tax rate) and a study by the Massachusetts Special Senate Committee on Marijuana (estimating $500 million in taxable sales) – and a third report with an estimate that was similar to their own (a study by ArcView Market Research estimating $1.07 billion in taxable sales in 2020).

emergency room or urgent care visits and the prevalence of low birth weight, obesity, tobacco use or nicotine dependence, and non-fatal vehicular crashes. We also did not include changes in spending related to poison control center costs because the changes were estimated to be quite small. It is possible that adult use of marijuana legalization could lead to changes in marijuana consumption that would in turn affect these and other public health outcomes. Finally, we did not factor in potential spending related to increases in energy or water use related to marijuana growth and production. Second, because literature on adult use of marijuana is sparse, our model estimates rely mainly on the medical marijuana literature. That is, we assumed that changes observed when migrating from no legal marijuana to medical marijuana would be similar to changes observed when migrating from medical marijuana to adult use of marijuana. Ideally, causal impacts taken from the literature would reflect the impacts of shifting from a medical marijuana market to a market that includes medical and broader adult use of marijuana. The limited studies on adult use of marijuana legalization have not found statistically significant impacts from the expansion of medical marijuana to broader adult use. However, a recently published study provides additional evidence that supports our strategy to use medical marijuana impact estimates. Powell, Pacula, & Jacobson (2015) found that the relationship between medical marijuana laws and the reduction in opioid deaths is influenced by the type of medical marijuana laws that states implemented. They found that opioid deaths decreased only in states in which marijuana dispensaries were easily available to patients. In Massachusetts, the medical marijuana program is more tightly regulated than in other states, and the state has fewer legal medical marijuana patients per 1,000 people than many other states that have legalized medical marijuana. Moreover, the number of qualifying conditions for medical marijuana use in Massachusetts is fewer than those in other states and does not include chronic pain, which is a qualifying condition in 13 of the states that have legalized medical marijuana (ProcCon, 2017). Therefore, the impact of marijuana legalization in Massachusetts may not be fully realized prior to adult use legalization, and the impact of medical marijuana policies in states with more liberal guidelines may provide insight into the expected impact of adult use legalization in Massachusetts.
A third potential limitation of our model is that we assumed that each input metric acts independently of other metrics; therefore, we did not account for the correlations between metrics in our model. It is analytically feasible to incorporate relationships between metrics into the impact estimates, for example, by factoring in the price elasticity of demand to see how marijuana use changes as pricing changes.

Finally, it is not clear whether the impacts projected from our model will sustain beyond the two-year time frame. Most of the impacts in our model can be considered one-time (but not necessarily immediate) shifts as a result of legalization. For example, we may not expect marijuana-related arrests to further decrease beyond the two-year time frame, nor do we expect the start-up costs of establishing the regulatory framework to persist. However, impacts on consumption and associated public health outcomes may take longer to realize because they depend on market prices, the accessibility of dispensaries, and other factors that are associated with a high degree of uncertainty.

Directions for Future Research

The MBHS provides a valuable baseline understanding of the impacts of legalization in Massachusetts and serves as a benchmark to improve the implementation of marijuana legalization in other states. In this report, we synthesize information from a number of sources to provide projections that serve as a reference to compare to the actual experience in Massachusetts as the program unfolds. Such a comparison can be used to better understand the factors driving the fiscal impacts of adult use of marijuana and to project future impacts beyond the first two years of legalization. Our analysis should also help the state and localities anticipate what resources may be needed to roll out the adult use program.

References

Anderson, D. M., Hansen, B., & Rees, D. I. (2013). Medical marijuana laws, traffic fatalities, and alcohol consumption. *The Journal of Law and Economics*, *56*(2), 333-369. https://doi.org/10.1086/668812

Anderson, D. M., Hansen, B., & Rees, D. I. (2015). Medical marijuana laws and teen marijuana use. *American Law and Economics Review*, *17*(2), 495-528. https://doi.org/10.1093/aler/ahv002

Anderson, D. M., Rees, D. I., & Sabia, J. J. (2014, December). Medical marijuana laws and suicides by gender and age. *American Journal of Public Health*, *104*(12), 2369-2376. http://doi.org/10.2105/AJPH.2013.301612

Aos, S., Phipps, P., Barnoski, R., & Lieb, R. (2001). *The comparative costs and benefits of programs to reduce crime. Version 4* (Washington State Institute of Public Policy). Retrieved from Education Resources Information Center website: https://eric.ed.gov/?id=ED453340

Bachhuber, M. A., Saloner, B., Cunningham, C. O., & Barry C. L. (2014). Medical cannabis laws and opioid analgesic overdose mortality in the United States, 1999–2010. *JAMA Internal Medicine*, *174*(10), 1668–1673. http://doi.org/10.1001/jamainternmed.2014.4005

Birnbaum, H. G., White, A. G., Schiller, M., Waldman, T., Cleveland, J. M., & Roland, C. L. (2011). Societal costs of prescription opioid abuse, dependence, and misuse in the United States. *Pain Medicine, 12*(4), 657–667. http://doi.org/10.1111/j.1526-4637.2011.01075.x

Blincoe, L. J., Miller, T. R., Zaloshnja, E., & Lawrence, B. A. (2015, May). *The economic and societal impact of motor vehicle crashes, 2010 (revised)* (National Highway Traffic Safety Administration, DOT HS 812 013). Retrieved from U.S. Department of Transportation website: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013

Bradford, A. C., & Bradford, W. D. (2017). Medical marijuana laws may be associated with a decline in the number of prescriptions for Medicaid enrollees. *Health Affairs (Project Hope*), *36*(5), 945–951. http://doi.org/10.1377/hlthaff.2016.1135

Choo, E. K., Benz, M., Zaller, N., Warren, O., Rising, K. L., & McConnell, K. J. (2014). The impact of state medical marijuana legislation on adolescent marijuana use. *Journal of Adolescent Health, 55*(2), 160–166. http://doi.org/10.1016/j.jadohealth.2014.02.018

Chu, Y.W.L. (2015). Do medical marijuana laws increase hard-drug use? *The Journal of Law and Economics, 58*(2), 481–517. http://doi.org/10.1086/684043

Colorado Department of Revenue. (2018). Marijuana tax data. Retrieved from Colorado State website: https://www.colorado.gov/pacific/revenue/colorado-marijuana-tax-data

Committee on Foreign Affairs and International Trade, Senate of Canada, Ottawa, Canada (2018, March 22). Designing cannabis supply to promote temperance. (Testimony of Mark Kleiman) Retrieved from Marron Institute website: https://marroninstitute.nyu.edu/uploads/content/Designing_Cannabis_Supply_to_Promote_Temperance_-_Kleiman_Sep_2017.pdf

Cooper, W., Johnston, E., & Segal, K. (2016, April). *The economic impacts of marijuana sales in the state of California* (ICF International white paper). Retrieved from ICF International website: https://www.icf.com/resources/white-papers/2016/economic-impact-of-marijuana-sales-in-california

Darnell, A. J., & Bitney, K. (2017). *I-502 evaluation and benefit-cost analysis: Second required report* (Washington State Institute for Public Policy, 17-09-3201). Retrieved from Washington State Institute for Public Policy website: http://www.wsipp.wa.gov/ReportFile/1670/Wsipp_I-502-Evaluation-and-Benefit-Cost-Analysis-Second-Required-Report_Report.pdf

Dills, A., Goffard, S., & Miron, J. (2016, September 16). *Dose of reality: The effect of state marijuana legalizations* (CATO Institute Policy Analysis No. 799). Retrieved from the CATO website: https://object.cato.org/sites/cato.org/files/pubs/pdf/pa799.pdf

Dills, A. K., Goffard, S., & Miron, J. (2017). *The effects of marijuana liberalizations: Evidence from monitoring the future* (National Bureau of Economic Research No. w23779). http://doi.org/10.3386/w23779

Friese, B., Grube, J. W., & Moore, R. S. (2013). Youth acquisition of alcohol and drinking contexts: An in-depth look. *Journal of drug education*, *43*(4), 385-403. http://dx.doi.org/10.2190/DE.43.4.f

Harrison, L. D., Martin, S. S., Enev, T., & Harrington, D. (2007, May). *Comparing drug testing and self-report of drug use among youths and young adults in the general population.* Retrieved from Buckley’s Renewal Center website: http://www.buckleysrenewalcenter.com/wp-content/uploads/2012/02/drugtest.pdf

Hasin, D. S., Sarvet, A. L., Cerdá, M., Keyes, K. M., Stohl, M., Galea, S., & Wall, M. M. (2017). U.S. adult illicit cannabis use, cannabis use disorder, and medical marijuana laws: 1991–1992 to 2012–2013. *JAMA Psychiatry, 74*(6), 579–588. http://doi.org/10.1001/jamapsychiatry.2017.0724

Hasin, D. S., Wall, M., Keyes, K. M., Cerdá, M., Schulenberg, J., O'Malley, P. M., Galea, S., Pacula, R., & Feng., T. (2015). Medical marijuana laws and adolescent marijuana use in the USA from 1991 to 2014: Results from annual, repeated cross-sectional surveys. *The Lancet Psychiatry, 2*(7), 601–608. http://doi.org/10.1016/S2215-0366(15)00217-5

Hunt, P., & Pacula, R. L. (2017). Early impacts of marijuana legalization: An evaluation of prices in Colorado and Washington. *Journal of Primary Prevention, 38*(3), 221–248. http://doi.org/10.1007/s10935-017-0471-x

Jamison, E., Mintz, S., Herndon, K., & Bol, K. (2017, October). Suicide in Colorado, 2011-2015: A summary from the Colorado Violent Death Reporting System. *Health Watch, 102*. Retrieved from Colorado State website: https://www.colorado.gov/pacific/sites/default/files/CHED_CoVDRS_HealthWatch_Suicide-in-Colorado-2011-2015-Colorado-Violent-Death-Reporting-System_1017%20.pdf

Joint Committee on Marijuana Policy (2017, March 20) (Testimony of Commissioner Michael Heffernan, Massachusetts Department of Revenue).

Kilmer, B., Caulkins, J. P., Midgette, G., Dahlkemper, L., MacCoun, R. J., & Pacula, R. L. (2013). *Before the grand opening: Measuring Washington State's marijuana market in the last year before legalized commercial sales.* Retrieved from RAND Corporation website: https://www.rand.org/pubs/research_reports/RR466.html

Light, M., Orens, A., Rowberry, J., & Saloga, C.W. (2016, October). *The economic impact of marijuana legalization in Colorado.* Retrieved from Marijuana Policy Group website: http://mjpolicygroup.com/pubs/MPG%20Impact%20of%20Marijuana%20on%20Colorado-Final.pdf

Marijuana Policy Project. (2018, February 26). *Medical marijuana patient numbers.* Retrieved from MPP website: https://www.mpp.org/issues/medical-marijuana/state-by-state-medical-marijuana-laws/medical-marijuana-patient-numbers/

Migoya, D. (2017, August 27). Traffic fatalities linked to marijuana are up sharply in Colorado. Is legalization to blame? *The Denver Post.* Retrieved from https://www.denverpost.com/2017/08/25/colorado-marijuana-traffic-fatalities/

Nicholas, L. H. & Maclean, J. C. (2016). *The impact of medical marijuana laws on the labor supply and health of older adults: Evidence from the Health and Retirement Study* (National Bureau of Economic Research, No. w22688). Retrieved from Social Science Research Network website: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2846904

Oregon Department of Revenue. (n.d.). *Oregon marijuana tax statistics.* Retrieved from Oregon State website: http://www.oregon.gov/dor/programs/gov-research/pages/research-marijuana.aspx

Powell, D., Pacula, R. L., & Jacobson, M. (2015). *Do medical marijuana laws reduce addictions and deaths related to pain killers?* (National Bureau of Economic Research, No. w21345). http://dx.doi.org/10.3386/w21345

Pozzi, F., & Small, C. (2005, June). Analysis of urban land cover and population density in the United States. *Photogrammetric Engineering & Remote Sensing, 71*(6), 719–726. Retrieved from American Society for Photogrammetry and Remote Sensing website: https://www.asprs.org/wp-content/uploads/pers/2005journal/jun/2005_jun_719-726.pdf

ProCon. (2016, March 3). *Number of legal medical marijuana patients.* Retrieved from ProCon website: https://medicalmarijuana.procon.org/view.resource.php?resourceID=005889

ProCon. (2017, November 20). *29 legal medical marijuana state and DC: Laws, fees, and possession limits.* Retrieved from ProCon website: https://medicalmarijuana.procon.org/view.resource.php?resourceID=000881Massachusetts

Ruggles, S., Genadek, K., Goeken, R., Grover, J., & Sobek, M. (2017). *Integrated public use microdata series: Version 7.0* [Data file]. Minneapolis: University of Minnesota.

Russell, E. M., Cook, K. R., Gold-Alexander, D., Rollins, R. S., Wilson, P., Wong, L., & Cerasoli, R. (2017, December 27). *Alcoholic Beverages Control Commission of Massachusetts: Task force report.* Retrieved from Massachusetts State website: https://www.mass.gov/files/documents/2017/12/28/Alcohol%20Task%20Force%20Report_0.pdf

Sabia, J., & Nguyen, T. T. (2016, March). *The effect of medical marijuana laws on labor market outcomes* (IZA Discussion Paper, 9831). Retrieved from IZA Institute of Labor Economics website: http://ftp.iza.org/dp9831.pdf

Santaella-Tenorio, J., Mauro, C., Wall, M., Kim, J., & Martins, S. (2017). Reductions in traffic fatalities rates across states with operational dispensaries of marijuana. *Drug and Alcohol Dependence, 171*. http://doi.org/10.1016/j.drugalcdep.2016.08.500

Shepard, D. S., Gurewich, D., Lwin, A. K., Reed, G. A., Jr., & Silverman, M. M. (2015). Suicide and suicidal attempts in the United States: Costs and policy implications. *Suicide and Life-Threatening Behavior*, *46*(3), 352–362. https://doi.org/10.1111/sltb.12225

Tefft, B. C., Arnold, L. S., & Grabowski, J. G. (2016). *Prevalence of marijuana use among drivers in fatal crashes: Washington, 2010-2014.* Retrieved from AAA Foundation for Traffic Safety website: https://aaafoundation.org/prevalence-marijuana-use-among-drivers-fatal-crashes-washington-2010-2014/

United States Census Bureau. (2015). *B01001: Sex by age. 2011–2015 American Community Survey*. Washington, DC: U.S. Census Bureau, American Community Survey.

Washington State Liquor and Cannabis Board. (n.d.). *Marijuana dashboard.* Retrieved from Washington State website: https://data.lcb.wa.gov/stories/s/%20WSLCB-Marijuana-Dashboard/hbnp-ia6v/

Wen, H., Hockenberry, J., & Cummings, J. R. (2014). *The effect of medical marijuana laws on marijuana, alcohol, and hard drug use* (National Bureau of Economic Research, No. w20085). http://doi.org/10.3386/w20085

Wen, H., Hockenberry, J. M., & Cummings, J. R. (2015). The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. *Journal of Health Economics, 42,* 64–80. http://doi.org/10.1016/j.jhealeco.2015.03.007

Wide Open Eats. (2017). *How much each state pays for a case of beer on average.* Retrieved from Wide Open Eats website: http://www.wideopeneats.com/much-case-beer-costs-state/

Appendix

Appendix A

DPH Statewide Survey Tool

Draft

Massachusetts Survey of Health and Social Behavior: Marijuana Baseline Health Study

Please have the adult in your household (18 years or older) who is a Massachusetts resident and had the most recent birthday complete this survey. We do not mean the oldest person. We mean the person who had a birthday last. While every question is important to our study, this survey is completely voluntary and you can skip any question.

If you would prefer to complete this survey online, please go to:

http://TinyURL.com/HealthSurveyMA

Instructions for Completing the Booklet

This booklet contains several types of questions. Each question should be answered only about yourself, not anyone else in your household.

- For some questions, you answer the question by marking a box, like this (please mark only one box, unless directed otherwise):
  ☒ Yes
  ☐ No
- For some questions, you answer the question by filling in one number per box, like this:
  | 0 | 9 |
- You will sometimes be instructed to skip one or more questions. In this example, if your choice is 'No', you skip to question 10; otherwise, you continue to the next question.
  ☐ Yes
  ☒ No → *Go To Question 10*

Thank you for taking the survey. Please check one box for each question unless the directions ask you to do otherwise.

Household Demographics

1. How many adults age 18 years or older live in your household? *(Please fill in the number.)*

☐☐ *Number of adults*

2. How many children under 18 years old live in your household?

☐☐ *Number of children*

3. Many people only live in Massachusetts for part of the year. Do you live in Massachusetts for 6 or more months out of the year?

☐ Yes
☐ No

4. In what year were you born?

☐☐☐☐ *Year*

5. What is your gender?

☐ Male
☐ Female
☐ Other

6. Are you Hispanic or Latino?

☐ Yes
☐ No

7. Which one or more of the following would you say is your race? *(Check all that apply.)*

☐ White or Caucasian
☐ Black or African American
☐ Asian
☐ Native Hawaiian or Other Pacific Islander
☐ Native American or Alaskan Native
☐ Some other race

1

Draft

8. **What is the highest degree or level of school you have completed?**
   - ☐ Never attended school or only attended kindergarten
   - ☐ Grades 1 through 8
   - ☐ Grades 9 through 11
   - ☐ Regular high school diploma or GED
   - ☐ Some college credit, but less than one year of college credit
   - ☐ One or more years of college credit, no degree
   - ☐ Associate degree
   - ☐ Bachelor's degree
   - ☐ Master's degree
   - ☐ Professional degree beyond a bachelor's degree
   - ☐ Doctorate degree

9. **What is your annual household income from all sources?**
   - ☐ Less than $15,000
   - ☐ $15,000 – $29,999
   - ☐ $30,000 – $49,999
   - ☐ $50,000 – $99,999
   - ☐ $100,000 – $149,999
   - ☐ $150,000 or more

10. **What is the zip code where you currently live?**

    ☐☐☐☐☐ *Zip Code*

11. **What type of healthcare coverage do you have?** *(Check all that apply.)*
    - ☐ Private commercial or group plan (for example, an HMO or PPO through an employer)
    - ☐ Medicare
    - ☐ Medicaid
    - ☐ Commonwealth Care Program (Health Connector)
    - ☐ Indian Health Services
    - ☐ Veterans Affairs (VA)
    - ☐ No Health Insurance
    - ☐ Other plan

12. **Do you own the place where you currently live, pay rent, or something else?**
    - ☐ Own
    - ☐ Rent
    - ☐ Something else

Opinion

In 2016, Massachusetts voters legalized marijuana for recreational use. We are trying to understand how this change may affect the attitudes and behaviors of Massachusetts residents.

13. **Do you believe that marijuana should be legal for recreational use in Massachusetts?**
    - ☐ Yes
    - ☐ No

14. **How much do you think people risk harming themselves (physically or in other ways) if they use marijuana regularly?**
    - ☐ No risk
    - ☐ Slight risk
    - ☐ Moderate risk
    - ☐ Great risk

Social Behaviors

Now we will ask about some of your social behaviors. Please remember that this survey is private and confidential. Each question should be answered only about you, not anyone else in the household.

Alcohol Consumption

The next set of questions is about alcohol. One drink of alcohol is equal to a 12-ounce beer, a 5-ounce glass of wine, or a drink with one shot of liquor.

15. **During the past 30 days, did you have at least one drink of any alcoholic beverage such as beer, wine, a malt beverage, or liquor?**
    - ☐ Yes
    - ☐ No → ***Go To Question 20***

Draft

16. **During the past 30 days, how many days per week did you have at least one drink of any alcoholic beverage?**

☐ *Days per week*

17. **During the past 30 days, about how much money did you spend on alcohol in total?** *(Only include alcohol that you consumed. Do not include alcohol that you purchased for other purposes, such as gifts or storage.)*

$ ☐ , ☐☐☐ *Dollars*

18. **During the past 12 months, how many times were you treated in an emergency room or urgent care facility for any reason related to alcohol use?**

- ☐ 0 times
- ☐ 1 time
- ☐ 2–3 times
- ☐ 4–5 times
- ☐ 6 or more times

19. **During the past 30 days, how many times have you driven a car or other motor vehicle while you were under the influence of alcohol?**

- ☐ 0 times
- ☐ 1 time
- ☐ 2–3 times
- ☐ 4–5 times
- ☐ 6 or more times

20. **During the past 30 days, how many times did you ride as a passenger in a car or other motor vehicle when the driver was under the influence of alcohol?**

- ☐ 0 times
- ☐ 1 time
- ☐ 2–3 times
- ☐ 4–5 times
- ☐ 6 or more times

Marijuana

The next set of questions is about marijuana. People sometimes call this cannabis, weed, pot, grass, ganje, hashish, hash, or other terms. Please remember that this survey is private and confidential. Each question should be answered only about you, not anyone else in the household.

21. **During the past 30 days, did you use marijuana or hashish at least once?**

- ☐ Yes
- ☐ No → ***Go To Question 28***

22. **During the past 30 days, on how many days did you use marijuana or hashish?**

☐☐ *Days*

23. **During the past 30 days, which of the following purposes did you use marijuana for?** *(Check all that apply.)*

- ☐ Recreational use (Non-medical)
- ☐ Medical use (Prescribed by a qualified physician)
- ☐ Medical use (Not prescribed by a qualified physician)

24. **During the past 30 days, how did you use marijuana?** *(Check all that apply.)* **Did you:**

- ☐ Smoke it (in a joint, bong, pipe, or blunt)
- ☐ Eat it (in brownies, cakes, cookies, or candy)
- ☐ Drink it (in tea, cola, alcohol)
- ☐ Vaporize it (in an e-cigarette-like vaporizer)
- ☐ Dab it (using butane hash oil, wax, or concentrates)
- ☐ Apply it topically on the skin (using cannabis oil, cannabis ointment/lotion, or topical cannabis salve)
- ☐ Use rectal cannabis suppositories
- ☐ Use sublingual (under-the-tongue) uptake products (dissolvable strips, sublingual sprays, or medicated lozenges)

25. **During the past <u>30 days</u>, about how much money did you spend on marijuana in total?** *(Only include marijuana that you consumed. Do not include marijuana that you purchased for other purposes, such as gifts or storage.)*

$ ☐ , ☐☐☐ *Dollars*

26. **During the past <u>12 months</u>, how many times were you treated in an emergency room or urgent care facility for any reason related to marijuana use?**
- ☐ 0 times
- ☐ 1 time
- ☐ 2–3 times
- ☐ 4–5 times
- ☐ 6 or more times

27. **During the past <u>30 days</u>, how many times did you drive a car or other motor vehicle when you were under the influence of marijuana or hashish?**
- ☐ 0 times
- ☐ 1 time
- ☐ 2–3 times
- ☐ 4–5 times
- ☐ 6 or more times

28. **During the past <u>30 days</u>, how many times did you ride as a passenger in a car or other motor vehicle when the driver was under the influence of marijuana or hashish?**
- ☐ 0 times
- ☐ 1 time
- ☐ 2–3 times
- ☐ 4–5 times
- ☐ 6 or more times

Other Substances

The next set of questions is about substance use other than alcohol or marijuana, both prescription drugs used for non-medical purposes and other substances. Please remember that this survey is private and confidential. Each question should be answered only about you, not anyone else in the household.

"Non-medical" prescription drug use means using it to get high or experience pleasurable effects, see what the effects are like, or use with friends.

29. **During the past <u>30 days</u>, did you use any of the following drugs?** *(Check all that apply.)* **Did you use . . .**
- ☐ Cocaine or Crack
- ☐ Heroin
- ☐ Non-medical use of antianxiety drugs such as Sedatives/Tranquilizers/Anxiolytics or sleeping drugs such as Benzodiazepines/Barbituates
- ☐ Non-medical use of prescription opioids such as Oxycodone/OxyContin, Hydrocodone/Vicodin, Morphine, Methadone, Fentanyl
- ☐ Other *(Please write in your answer):* ____________________
- ☐ None→ *Go To Question 34*

30. **During the past <u>30 days</u>, on how many days did you use the drug or drugs that you indicated in the previous question?**

☐☐ *Days*

31. **During the past <u>30 days</u>, about how much money did you spend on drugs, either prescription drugs or other substances, in total?** *(Only include drugs that you consumed. Do not include drugs that you purchased for other purposes, such as gifts or storage.)*

$ ☐ , ☐☐☐ *Dollars*

Appendix B

DPH Patient Survey Tool

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH

MARIJUANA BASELINE HEALTH STUDY

MEDICAL USE OF MARIJUANA PATIENT SURVEY

Dear Participant,

Thank you for taking the time to complete this survey on medical use of marijuana.

The purpose of this survey is to better understand the patterns of use and perceptions among medical use of marijuana patients in Massachusetts. The information you provide will help to inform the safe use and implementation of marijuana legalization in Massachusetts. This survey will ask questions about your use of marijuana and other substances. There is a small risk that some of the questions may make you feel uncomfortable.

Filling out this survey is completely voluntary. You do not have to answer any question you do not want to. You can stop this survey at any time. Choosing to not participate in this survey will not affect your access to marijuana or any other related service.

All information that you provide is confidential. You will be asked to provide your unique Registration Number that is visible on your Program ID card to complete the survey. You will not be asked to provide your name or any other identifying information. Your responses will not be tied back to you in a way that can be identified. Your name or any other identifying information will not be tied to your responses.

This research study has been reviewed by the Massachusetts Department of Public Health (MDPH) Institutional Review Board (IRB). The Commissioner of the Massachusetts Department of Public Health has approved this study in accordance with Massachusetts General Law c. 111 s. 24A. This law protects the confidentiality of all information collected for this study. This law states that the information we collect is not available as a public record. It may not be used as evidence in any legal proceedings. This means that individually identifying information about you will not be shared with anyone outside the study team. It will not be used for any purpose other than for this study.

This survey will include questions on the following topics:

Basic information about you (your age, your racial identity, and what county you live in)
Your current and past experiences regarding the use of marijuana for medical purposes
Your current and past experiences using other drugs

This survey should take between 20-30 minutes to complete.

There are no direct benefits to all participants as a result of participating in this survey. However, as an incentive for your participation, you will be asked at the end of this survey if you would like to be entered into a drawing to win a gift card worth $100, $250, or $500. If you would like to participate, your identifier will be entered into a pool with other participants for the chance to win a gift card. If your identifier is chosen as a winner you will be contacted through email to receive your gift.

If you have any questions about this survey, please contact [redacted] or at MBHS@state.ma.us.

For more information about your rights as a research participant, please contact the MDPH IRB at (617) 624-5621.

Thank you again for your time today.

Demographics

1. What is your age?
18 to 25
26 to 35
36 to 50
51 to 64
65+

2. What is your gender?
Male
Female
Other, please specify: ___________*
Refuse to answer

3. Are you currently pregnant?
Yes
No
Don’t Know/Not sure
Refuse to Answer

4. Are you currently breastfeeding?
Yes
No
Don't know/Not sure
Refuse to answer

5. Are you Hispanic or Latino?
Yes
No
Don't know/Not sure
Refuse to answer

6. What is your race? *Please select all that apply*.
White or Caucasian
Black or African American
Asian
Native Hawaiian or Other Pacific Islander
American Indian or Alaska Native
Other, please specify: ___________*
Don't know/Not sure
Refuse to answer

7. What is the highest grade or year of school you have completed?
Never attended school or only attended kindergarten
Grades 1-8
Grades 9-11
Regular high school diploma or GED
Trade school certificate/diploma
Some college credit, but less than one year of college credit
One or more years of college credit, no degree
Associate degree
Bachelor's degree
Master's degree
Professional degree beyond a Bachelor's degree
Professional degree beyond a Master’s degree
Doctoral degree

8. What is your annual household income from all sources?
Less than $15,000
$15,000 to $24,999
$25,000 to $39,999
$40,000 to $59,999
$60,000 to $74,999
$75,000 to $99,999
$100,000 to $149,999
$150,000 to $199,999
$200,000 or more
Don’t know/Not sure
Refuse to answer

9. What is the county where you currently live?
Barnstable
Berkshire
Bristol
Dukes
Essex
Franklin
Hampden
Hampshire
Middlesex
Nantucket
Norfolk
Plymouth
Suffolk
Worcester
Don't know/Not sure
Refuse to answer

10. Do you currently identify as having an ambulatory disability that limits your ability to be mobile?*
Yes, I have an ambulatory disability
No, I do not have an ambulatory disability
Don't know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use

11. During the past 30 days, on how many days did you use marijuana or marijuana products?
Number of days (1-30): ___________*
None (0 days) – Skip to Q53
Don't know/Not sure
Refuse to answer

12. During the past 30 days, which of the following purpose(s) did you use marijuana or marijuana products for and on how many days? *Please select all that apply.*
Recreational use (Non-medical, e.g., to get high). Number of days (1-30): _____
Medical use certified by a qualified practitioner. Number of days (1-30): _____
Medical use NOT certified by a qualified practitioner. Number of days (1-30): _____
Don't know/Not sure
Refuse to answer

If you do not use marijuana or marijuana products for medical use (certified or not certified), then skip to Q15.

If you are not taking this survey with a computer or tablet, then skip to Q14.

13.* If you use marijuana for medical purposes, please indicate which medical condition(s) you use marijuana or marijuana products for. *Please select all that apply.
ADHD
Alcohol Dependency
Anxiety
Arthritis
Asthma
Bipolar Disorder
Bowel Distress
Cancer
Carpal Tunnel
Chronic Pain
Crohn’s Disease
Depression
Diabetes
Fibromyalgia

Glaucoma
Headaches/Migraines
Hepatitis C
HIV/AIDS
Huntington's Disease
Hypertension
Insomnia
Loss of Appetite
Multiple Sclerosis
Muscle Spasms
Muscular Dystrophy
Nausea
Neuropathy
OCD
Opioid Use
Osteoarthritis
PTSD
Schizophrenia
Seizures
Skin Conditions
Sleep Apnea
Stress
Tourette's Syndrome
Tremors
Vomiting
Wasting
Weight Loss
Other, please specify: ________________*
Don't know/Not sure
Refuse to answer

If you are not taking this survey with a smartphone, then skip to Q15.

14. If you use marijuana for medical purposes, please indicate which medical condition(s) you use marijuana or marijuana products for. *Please select all that apply.*

ADHD
Alcohol Dependency
Anxiety
Arthritis
Asthma
Bipolar Disorder
Bowel Distress
Cancer
Carpal Tunnel
Chronic Pain
Crohn's Disease

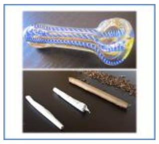
Depression
Diabetes
Fibromyalgia
Glaucoma
Headaches/Migraines
Hepatitis C
HIV/AIDS
Huntington’s Disease
Hypertension
Insomnia
Loss of Appetite
Multiple Sclerosis
Muscle Spasms
Muscular Dystrophy
Nausea
Neuropathy
OCD
Opioid Use
Osteoarthritis
PTSD
Schizophrenia
Seizures
Skin Conditions
Sleep Apnea
Stress
Tourette’s Syndrome
Tremors
Vomiting
Wasting
Weight Loss
Other, please specify: ________________*
Don't know/Not sure
Refuse to answer

15. Do you typically use marijuana or marijuana products that are higher in THC (delta-9-tetrahydrocannabinol), higher in CBD (cannabidiol), or that contain somewhat equal amounts of THC and CBD?
Higher in THC
Higher in CBD
Contain somewhat equal amounts of THC and CBD
Don’t know/Not sure
Refuse to answer

If you are not taking this survey with a computer or tablet, then skip to Q17.

16. **What method(s) of marijuana administration have you used (one time or more) in the past 30 days? *Please select all that apply.***

Smoked dried flower



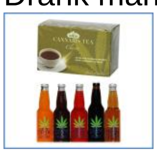
Vaporized dried flower

Vaporized concentrate (cartridge/vape oil)

Dabbed marijuana products (butane hash oil, wax, shatter, etc.)

Ate marijuana products (brownies, cakes, cookies, etc.)

Drank marijuana infused products (tea, cola, alcohol, etc.)



Used sublingual (under the tongue) or orally administered uptake products (dissolvable strips, sublingual sprays, oils, tinctures, medicated lozenges, etc.)

Used oral capsules/tablets

Applied topical cannabis oil, ointment, lotion, cream, salve, etc. to your skin

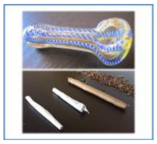
Used rectal/vaginal cannabis suppositories

Other

If you are not taking this survey with a smartphone, then skip to Q18.

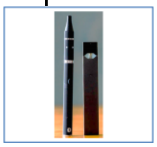
17. What method(s) of marijuana administration have you used (one time or more) in the past 30 days? *Please select all that apply.*

Smoked dried flower



Vaporized dried flower

Vaporized concentrate (cartridge/vape oil)



Dabbed marijuana products (butane hash oil, wax, shatter, etc.)

Ate marijuana products (brownies, cakes, cookies, etc.)

Drank marijuana infused products (tea, cola, alcohol, etc.)

Used sublingual (under the tongue) or orally administered uptake products (dissolvable strips, sublingual sprays, oils, tinctures, medicated lozenges, etc.)

Used oral capsules/tablets

Applied topical cannabis oil, ointment, lotion, cream, salve, etc. to your skin

Used rectal/vaginal cannabis suppositories

Other

If you are do not administer marijuana or marijuana products in and "Other" way, skip to Q19.

18. **Please specify the "Other" form marijuana administration you have used (one time or more) in the past 30 days.**

    ____

Marijuana and Marijuana Product Use
If you have not "Smoked dried flower" in the past 30 days, skip to Q22.

---

19. **How frequently did you <u>smoke dried flower</u> in a joint, bong, pipe, blunt, etc. in the past 30 days?**

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don't know/Not sure
Refuse to answer

If you are not taking this survey with a computer or tablet, then skip to Q21.

20. How much <u>dried flower</u> did you smoke in the past 30 days? *Below is a visual guide for dried flower quantities.*

Less than 1 gram
1 to 3 grams
1/8 ounce (or about 3.5 grams)
1/4 ounce (or about 7.0 grams)
1/2 ounce (or about 14.2 grams)
3/4 ounce (or about 21.3 grams)
1 ounce (or about 28.4 grams)
More than 1 ounce (more than 28.4 grams), please specify: ___________*
Don’t know/Not sure
Refuse to answer

If you are not taking this survey with a smartphone, then skip to Q22.

21. How much <u>dried flower</u> did you smoke in the past 30 days? *Below is a visual guide for dried flower quantities.*

Less than 1 gram
1 to 3 grams
1/8 ounce (or about 3.5 grams)

1/4 ounce (or about 7.0 grams)
1/2 ounce (or about 14.2 grams)
3/4 ounce (or about 21.3 grams)
1 ounce (or about 28.4 grams)
More than 1 ounce (more than 28.4 grams), please specify: ___________*
Don’t know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not “Vaporized dried flower” in the past 30 days, skip to Q25.

---

22. How frequently did you <u>vaporize dried flower</u> in an e-cigarette-like vaporizer in the past 30 days?
Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don’t know/Not sure
Refuse to answer

If you are not taking this survey with a computer or tablet, then skip to Q24.
23. How much <u>dried flower</u> did you vaporize in the past 30 days? *Below is a visual guide for dried flower quantities.*

Less than 1 gram
1 to 3 grams
1/8 ounce (or about 3.5 grams)
1/4 ounce (or about 7.0 grams)
1/2 ounce (or about 14.2 grams)
3/4 ounce (or about 21.3 grams)
1 ounce (or about 28.4 grams)
More than 1 ounce (more than 28.4 grams), please specify: ___________*
Don’t know/Not sure
Refuse to answer

If you are not taking this survey with a smartphone, then skip to Q25.

24. How much <u>dried flower</u> did you vaporize in the past 30 days? *Below is a visual guide for dried flower quantities.*

Less than 1 gram
1 to 3 grams
1/8 ounce (or about 3.5 grams)
1/4 ounce (or about 7.0 grams)
1/2 ounce (or about 14.2 grams)
3/4 ounce (or about 21.3 grams)
1 ounce (or about 28.4 grams)
More than 1 ounce (more than 28.4 grams), please specify: ___________*
Don’t know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not “Vaporized marijuana concentrate” in the past 30 days, skip to Q28.

---

25. How frequently did you <u>vaporize marijuana concentrate</u> (cartridge/vape oil) in an e-cigarette-like or other vaporizer in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don’t know/Not sure
Refuse to answer

26. How much THC did you administer in total in the past 30 days by vaporizing concentrate/vape oil?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don't know/Not sure
Refuse to answer

27. How much CBD did you administer in total in the past 30 days by vaporizing concentrate/vape oil?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don't know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not "Dabbed marijuana products" in the past 30 days, skip to Q31.

28. How frequently did you dab marijuana products (butane hash oil, wax, shatter, or other concentrates) in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don't know/Not sure
Refuse to answer

29. How much <u>THC</u> did you administer in total in the past 30 days <u>by dabbing butane hash oil, wax, shatter, or other concentrates</u>?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don't know/Not sure
Refuse to answer

30. How much <u>CBD</u> did you administer in total in the past 30 days <u>by dabbing butane hash oil, wax, shatter, or other concentrates</u>?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don't know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not "Ate marijuana or marijuana products" in the past 30 days, skip to Q34.

---

31. How frequently did you <u>eat marijuana or marijuana products</u> in brownies, cakes, cookies, candy, etc. in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don't know/Not sure
Refuse to answer

32. How much <u>THC</u> did you administer in total in the past 30 days <u>by eating marijuana products (brownies, cakes, cookies, candy, etc.)</u>?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don't know/Not sure
Refuse to answer

33. How much <u>CBD</u> did you administer in total in the past 30 days <u>by eating marijuana products (brownies, cakes, cookies, candy, etc.)</u>?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don't know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not "Drank marijuana infused products" in the past 30 days, skip to Q37.

---

34. How frequently did you <u>drink marijuana infused products</u> in tea, cola, alcohol, etc. in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don't know/Not sure
Refuse to answer

35. How much THC did you administer in total in the past 30 days by drinking marijuana infused products (tea, cola, alcohol, etc.)?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don't know/Not sure
Refuse to answer

36. How much CBD did you administer in total in the past 30 days by drinking marijuana infused products (tea, cola, alcohol, etc.)?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don't know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not "Used sublingual (under-the-tongue) or orally administered uptake products" in the past 30 days, skip to Q40.

---

37. How frequently did you use sublingual (under-the-tongue) or orally administered uptake products (dissolvable strips, sublingual sprays, oils, tinctures, medicated lozenges, etc.) in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don't know/Not sure
Refuse to answer

38. How much <u>THC</u> did you administer in total in the past 30 days <u>by using sublingual (under-the-tongue) or orally administered uptake products (dissolvable strips, sublingual sprays, tinctures, medicated lozenges, etc.)</u>?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don’t know/Not sure
Refuse to answer

39. How much <u>CBD</u> did you administer in total in the past 30 days <u>by using sublingual (under-the-tongue) or orally administered uptake products (dissolvable strips, sublingual sprays, tinctures, medicated lozenges, etc.)</u>?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don’t know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not “Used oral capsules/tablets” in the past 30 days, skip to Q43.

---

40. How frequently did you <u>use oral capsules/tablets</u> (THC and/or CBD pills) in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don’t know/Not sure
Refuse to answer

41. How much <u>THC</u> did you administer in total in the past 30 days <u>by using oral capsules/tablets</u>?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don't know/Not sure
Refuse to answer

42. How much <u>CBD</u> did you administer in total in the past 30 days <u>by using oral capsules/tablets</u>?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don't know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not "Applied topical cannabis oil, ointment, lotion, salve, etc." in the past 30 days, skip to Q46.

---

43. How frequently did you <u>apply topical cannabis oil, ointment, lotion, salve, etc.</u> to your skin in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don't know/Not sure
Refuse to answer

44. How much <u>THC</u> did you administer in total in the past 30 days <u>by applying topical cannabis oil, ointment, lotion, salve, etc. to your skin</u>?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don’t know/Not sure
Refuse to answer

45. How much <u>CBD</u> did you administer in total in the past 30 days <u>by applying topical cannabis oil, ointment, lotion, salve, etc. to your skin</u>?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don’t know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not “Used rectal/vaginal cannabis suppositories” in the past 30 days, skip to Q49.

---

46. How frequently did you <u>use rectal/vaginal cannabis suppositories</u> in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don’t know/Not sure
Refuse to answer

47. How much <u>THC</u> did you administer in total in the past 30 days <u>by using rectal/vaginal cannabis suppositories</u>?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don't know/Not sure
Refuse to answer

48. How much <u>CBD</u> did you administer in total in the past 30 days <u>by using rectal/vaginal cannabis suppositories</u>?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don't know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use
If you have not "Use marijuana or marijuana products in some other way" in the past 30 days, skip to Q52.

---

49. How many times did you <u>use marijuana or marijuana products</u> in some other way (Q18 value) in the past 30 days?

Once in the past 30 days
2-3 times in the past 30 days
Once per week
2-3 times per week
4-6 times per week
Once per day
Several times per day
Don't know/Not sure
Refuse to answer

50. How much <u>THC</u> did you administer in total in the past 30 days <u>by some other way</u> (Q18 value)?

None in the past 30 days
Less than 10 mg THC
10 to 30 mg THC
30 to 70 mg THC
70 to 100 mg THC
100 to 150 mg THC
150 to 200 mg THC
200 to 300 mg THC
More than 300 mg THC, please specify: ___________*
Don’t know/Not sure
Refuse to answer

51. How much <u>CBD</u> did you administer in total in the past 30 days <u>by some other way</u> (Q18 value)?

None in the past 30 days
Less than 10 mg CBD
10 to 30 mg CBD
30 to 70 mg CBD
70 to 100 mg CBD
100 to 150 mg CBD
150 to 200 mg CBD
200 to 300 mg CBD
More than 300 mg CBD, please specify: ___________*
Don’t know/Not sure
Refuse to answer

Marijuana and Marijuana Product Use

52. During the past 30 days, about how much money did you spend on marijuana or marijuana products in total? Please enter zero if you spent no money on marijuana or marijuana products.

$: ___________*
Don't know/Not sure
Refuse to answer

Perceptions of Medical Use of Marijuana

53. How long have you been using marijuana or marijuana products for medical purposes?

0 – 3 months
3 – 6 months
6 – 12 months
1 – 3 years
Greater than 3 years, please specify: ___________*

54. When you buy medical marijuana at a licensed dispensary, how do you feel about your personal safety?

Very unsafe
Somewhat unsafe
Somewhat safe
Very safe
Don't know/Not sure
Refuse to answer

55. When selecting a marijuana product for your medical use, how would you rate your current knowledge of the recommended product based on information provided by your certified practitioner?

Very low
Somewhat low
Average
Somewhat high
Very high
Don't know/Not sure
Refuse to answer

56. When purchasing marijuana or marijuana products at a licensed dispensary, how confident do you feel that you are receiving a safe, uncontaminated product?

Very low confidence
Low confidence
Average confidence
Somewhat high confidence
Very high confidence
Don't know/Not sure
Refuse to answer

57. How effective do you feel marijuana or marijuana products have been in treating the medical condition for which you are using it?

Not effective at all
A little effective
Somewhat effective
Effective
Very Effective
Don't know/Not sure
Refuse to answer

Driving and Other Issues Related to Marijuana Use

58. Do you operate a motor vehicle at least once a week?*

Yes
No
Don't know/Not sure
Refuse to answer

59. During the past 30 days, how many times did you <u>drive/operate</u> a car or other motor vehicle when you were under the influence of (impaired from) marijuana or marijuana products?

0 times
1 time
2-3 times
4-5 times
6 or more times
Don't know/Not sure
Refuse to answer

60. During the past 30 days, how many times did you <u>ride as a passenger</u> in a car or other motor vehicle when the driver was under the influence of (impaired from) marijuana or marijuana products?

0 times
1 time
2-3 times
4-5 times
6 or more times
Don't know/Not sure
Refuse to answer

61. During the past 30 days, how many times were you treated in an emergency room or urgent care facility for any reason related to marijuana or marijuana product use?

Number of times: ___________*
No emergency/urgent care related to marijuana or marijuana product use in the past 30 days
Don't know/Not sure
Refuse to answer

If you have used marijuana or marijuana products for less than 6 months, skip to Q65.

62. In the past 12 months, have you needed to consume larger amounts of marijuana or marijuana products in order to feel the same effects?

Yes
No
Don't know/Not sure
Not applicable (has used marijuana less than 12 months)
Refuse to answer

63. In the past 12 months, have you tried to cut down on your marijuana or marijuana product use?

Yes
No – Skip to Q65
Don't know/Not sure – Skip to Q65
Not applicable (has used marijuana less than 12 months) – Skip to Q65
Refuse to answer – Skip to Q65

64. I**n the past 12 months, have you felt sick or had withdrawal symptoms because you stopped or cut down on your marijuana or marijuana product use?**

Yes
No
Don't know/Not sure
Not applicable (has used marijuana less than 12 months)
Refuse to answer

65. Have you noticed any of the following *negative* outcomes/consequences related to your marijuana use? *Please select all that apply.*

Negative changes in mood or mental health (worse depression, anxiety, etc.)
Reduction in physical health (you feel worse, can do fewer things, etc.)
Negative changes in cognition (difficultly thinking, remembering things, etc.)
Negative changes in social relationships
Occupation/job-related issues
Other, please specify: ___________*
No negative outcomes/consequences
Don’t know/Not sure
Refuse to answer

66. **Have you noticed any of the following *positive* outcomes/consequences related to your marijuana use? *Please select all that apply.***

Positive changes in mood or mental health (depression or anxiety is better, etc.)
Improved physical health (you feel better, can do more, etc.)
Positive changes in cognition (easier time thinking, better at remembering things, etc.)
Positive changes in social relationships
Other, please specify: ___________*
No positive outcomes/consequences
Don’t know/Not sure
Refuse to answer

Alcohol Consumption

67. **During the past 30 days, how many days did you have at least one drink of any alcoholic beverage such as beer, wine, a malt beverage or liquor?** *One* ***drink is equivalent to a 12-ounce beer, a 5-ounce glass of wine, or a drink with one shot of liquor.***

Number of days (1-30): ___________*
No drinks of alcohol in the past 30 days
Don't know/Not sure
Refuse to answer

68. **During the past 30 days, about how much money did you spend on alcohol in total? Please enter zero if you spent no money on alcohol. *We define expenditures on alcohol as the total amount spent on the alcohol consumed in the past 30 days and not alcohol purchased for other purposes like gifts or storage.***

$: ___________*
Don't know/Not sure
Refuse to answer

If you have not had at least one drink of any alcoholic beverage in the past 30 days, skip to Q70.

69. **During the past 30 days, how many times did you drive/operate a car or other motor vehicle while you were under the influence of alcohol? *We define vehicle as a motorized vehicle, like a car, truck, SUV, or motorcycle driven on a public roadway.***

0 times
1 time
2-3 times
4-5 times
6 or more times
Don't know/Not sure
Refuse to answer

70. During the past 30 days, how many times did you <u>ride as a passenger</u> in a car or other motor vehicle when the driver was under the influence of alcohol?

0 times
1 time
2-3 times
4-5 times
6 or more times
Don't know/Not sure
Refuse to answer

71. During the past 30 days, how many times were you treated in an emergency room or urgent care facility for any reason related to alcohol use?

Number of times: ___________*
No emergency/urgent care related to <u>alcohol use</u> in the past 30 days
Don't know/Not sure
Refuse to answer

Non-Medical Use of Prescription Drugs and Other Substances

---

72. During the past 30 days, did you use any of the following drugs for non-medical purposes (e.g., to get "high")? *Please select all that apply.*

Cocaine or Crack
Heroin
Antianxiety drugs such as (Sedatives/Tranquilizers/Anxiolytics)
Sleeping drugs such as (Benzodiazepines, Barbiturates)
Prescription opioids such as Oxycodone/OxyContin, Hydrocodone/Vicodin, Morphine, Methadone, Fentanyl
Other, please specify: ___________*
None of these – Skip to Q74
Don't know/Not sure – Skip to Q74
Refuse to answer – Skip to Q74

73. During the past 30 days, on how many days did you use any of the <u>drug(s) listed as answer choices above</u>?

Number of days (1-30): ___________*
Don't know/Not sure
Refuse to answer

74. Since beginning to use marijuana, have you cut down or stopped using any other prescription drugs, over the counter medications, or other substances?

Yes, please specify the substance(s) that were reduced or stopped: ___________*
No
Don't know/Not sure
Refuse to answer

75. During the past 30 days, about how much money did you spend on drugs, either prescription drugs or other substances, in total? Please enter zero if you spent no money on other drugs. *We define expenditures on other drugs as the total amount spent on the drug(s) listed above that were consumed in the past 30 days and non prescription drugs or other drugs purchased for other purposes like gifts or storage.*

$: ___________*
Don't know/Not sure
Refuse to answer

If you have not used drugs in Q72 for non-medical purposes, skip to Q77.

76. During the past 30 days, how many times did you drive/operate a car or other motor vehicle when you were unr the influence of any of the drug(s) indicated above?

0 times
1 time
2-3 times
4-5 times
6 or more times
Don't know/Not sure
Refuse to answer

77. During the past 30 days, how many times did you ride as a passenger in a car or other motor vehicle when the driver was under the influence of any of the drug(s) indicated above?

0 times
1 time
2-3 times
4-5 times
6 or more times
Don't know/Not sure
Refuse to answer

If you have not used drugs in Q72 for non-medical purposes, skip to Q79.

78. During the past 12 months, how many times were you treated in an emergency room or urgent care facility for any reason related to use of the drug(s) indicated above?

Number of times: ___________*
No emergency/urgent care treatment related to use of drugs indicated above in the past 12 months
Don't know/Not sure
Refuse to answer

Combination of Substances

79. During the past 30 days, on how many days did you use a combination of alcohol, marijuana, or other drugs, either prescription drugs or other substances?

Number of days (1-30): ____________*
None (0 days) – Skip to Q81
Don't know/Not sure – Skip to Q81
Refuse to answer – Skip to Q81

80. During the past 30 days, did you <u>drive/operate</u> a car or other vehicle when you were under the influence of (impaired from) any combination of alcohol, marijuana, or other drugs? For each option that you selected 'Yes', please also indicate the number of days in the past 30 days that you drove/operated a car or other vehicle when you were under the influence of the specified substances.

No
Yes, alcohol and marijuana. Number of days (1-30): ____________*
Yes, alcohol and other drugs. Number of days (1-30): ____________*
Yes, marijuana and other drugs. Number of days (1-30): ____________*
Yes, alcohol, marijuana, and other drugs. Number of days (1-30): ____________*
Don't know/Not sure
Refuse to answer

Health Study

If you have an ambulatory disability and do not operate a motor vehicle at least once a week, skip to Q82.

81. Would you be interested in learning more about participating in a health study assessing marijuana levels in the bodies of medical use of marijuana patients?

Yes *(A member from our study team may contact you)*
No

Random Prize Drawing

82. Would you like to be entered into a random prize drawing to win a gift card worth $100, $250, or $500 for your participation in this survey?

Yes *(We will notify you by email if you are a winner)*
No

Thank You!

You have reached the end of this survey. Thank you for your participation! If you have any questions about this survey, please call [redacted]

Appendix C

Economic and Fiscal Model Inputs

Table C.1. Model Inputs and Data Sources

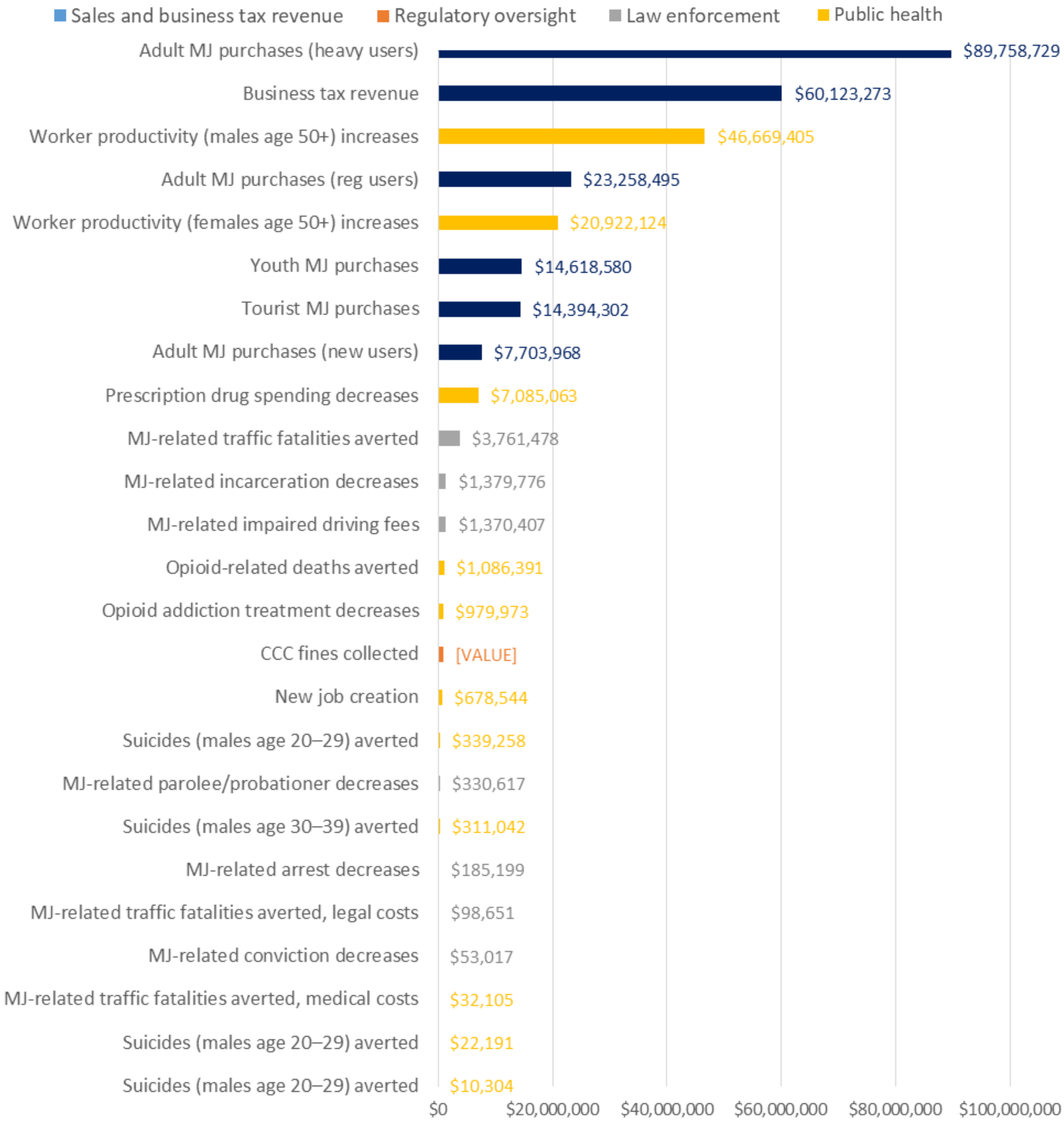
Input Metric	Estimate or Range	Data Source
Domain: Sales and Business Tax Revenue		
Marijuana Consumption by MA Residents		
Number of residents in MA		
Adolescent	970,444	2015 ACS
Adult	4,991,000	2015 ACS
Percentage of MA residents with current marijuana use		
Adolescent	8.7–24.0	2015 YHS, 2015 YRBSS, 2015–2016 NSDUH
Post-legalization percentage change	(5)–4.5	Anderson, Hansen, & Rees (2015); Choo et al. (2014); Hasin et al. (2015); Wen, Hockenberry, & Cummings (2015); Dills et al. (2017)
Percentage purchasing from RMDs	0–60	Friese, Grube, & Moore (2013), authors' assumption
Adult	8.6–12.1	2015 BRFSS, 2015 NSDUH
Post-legalization percentage change	15.9–16.6	Hasin et al. (2017); Wen et al. (2015)
Percentage shift from illicit to legal market	50–80	Stakeholder interview
Number of use days in past month, among users		
Regular users (1-20 use days per month)	7.26	Task 1 survey
Heavy users (21+ use days per month)	29.16	Task 1 survey
Percentage change in marijuana use days	12–17	Wen, Hockenberry, & Cummings (2014)
Percentage of users		
Regular users (1–20 use days per month)	67.94	Task 1 survey
Heavy users (21+ use days per month)	32.06	Task 1 survey
Grams of marijuana consumed each day of use		
Regular users (1-20 use days per month)	0.17–0.67	MBHS Task 1 survey, Kilmer et al. (2013)
Heavy users (21+ use days per month)	0.32–1.6	MBHS Task 1 survey, Kilmer et al. (2013)
Number of medical marijuana users	53872	
Current price of marijuana	\$13.3–\$13.7	RMD, Price of Weed, Budzu, Dispensary Sheets
Post-legalization percentage change	(50)–0	Stakeholder interview, WA State LCB (n.d.)
Tax rate	6.25% sales 10.75% excise 0-3% local	
Marijuana Consumption by Tourists		
Percentage of tax revenue generated from tourists	7–12	Light et al. (2016); Cooper et al. (2016)
Business tax rate on gross revenue	0.08	MA DOR
Beer Consumption		
Tax revenue from beer	72,830,435	Russell et al. (2017), Wide Open Eats (2017)

Input Metric	Estimate or Range	Data Source
Post-legalization percentage change in sales	(9.21–0.59)	Anderson, Hansen, & Rees (2013)
Domain: Regulatory Oversight		
State Regulatory and Law Enforcement		
Costs	$1,778,944	WSIPP, CCC
Revenue	$2,185,407	WSIPP, CCC
Domain: Law Enforcement		
Misdemeanor Arrests		
Unit cost	$1,188	Aos, Phipps, Barnoski, & Lieb (2001)
Number[a]	240	Stakeholder interview
Post-legalization percentage change	(50–80)	WSIPP, stakeholder interview
Misdemeanor Convictions		
Unit cost	$522	Aos et al. (2001)
Number[a]	159	Stakeholder interview
Post-legalization percentage change	(50–80)	WSIPP, stakeholder interview
Incarcerations		
Average annual cost of incarceration	$53,041	Aos et al. (2011)
Number[a]	40	Stakeholder interview
Post-legalization percentage change	(50–80)	WSIPP, stakeholder interview
Supervised Release (Parolees/Probationers)		
Average annual cost of parole	$4,180	Aos et al. (2011)
Number[a]	122	Stakeholder interview
Post-legalization percentage change	(50–80)	WSIPP, stakeholder interview
Traffic Fatalities		
Cost of cannabis impaired training	$655,000	Stakeholder interview
Legal cost per crash involving fatalities	$115,989	Blincoe, Miller, Zaloshnja, & Lawrence (2015)
Number	306	2015 FARS
Post-legalization percentage change	(11.4–9.8)	Anderson, Hansen, & Rees (2013); Santaella-Tenorio et al. (2017)
Domain: Public Health		
Medicaid prescription drug spending	$459,769,135	Bradford and Bradford (2017)
Post-legalization percentage change	(1.09–1.99)	Bradford and Bradford (2017)
Cannabis abuse or dependence		
Cost of treatment to the state	$2,086	Stakeholder interview
Treatment admissions	2,840	2016 TEDS
Post-legalization percentage change	10–27.2	Chu (2015); Wen et al. (2015); Hasin et al. (2017); Darnell & Bitney (2017)
Opioid abuse or dependence		
Cost of treatment to the state	$1,039–$4,221	Stakeholder interview, Birnbaum et al. (2011), 2011 TEDS
Treatment admissions	3,956	2016 TEDS
Post-legalization percentage change	(45.81)–22.47	Powell et al. (2015)
Averted Mortality		
Opioid-related mortality		
Number of overdose deaths	1,990	MPDH
Post-legalization percentage change	(18.00)–(17.90)	Powell et al. (2015); Bachhuber, Saloner, Cunningham, & Barry (2014)
Average income	$60,840	2015 ACS

Input Metric	Estimate or Range	Data Source
Suicides		
Cost of a suicide to the state	$39,887	Shepard, Gurewich, Lwin, Reed, & Silverman (2015)
Number of suicides, males age 20–29	76	2015 CDC Vital Statistics
Post-legalization percentage change	(18.8)–(3.8)	Anderson, Rees, & Sabia (2014)
Average income, males age 20–29	$24,228	2015 ACS
Number of suicides, males age 30–39	77	2015 CDC Vital Statistics
Post-legalization percentage change	(17.5)–(2.4)	Anderson, Rees, & Sabia (2014)
Average income, males age 30–39	$56,913	2015 ACS
Traffic fatalities	*see Law Enforcement section above*	
Average income	*see Opioid-related mortality above*	
Worker Productivity		
Number of recreational dispensaries	123	MDPH estimate
Average salary for minimum wage full-time employees[a,b]	$22,000	$11/hr, 40 hrs/wk, 50 wks/yr
Income tax rate	0.05	MA DOR
Number of FTEs at minimum wage per dispensary previously unemployed or working in illicit market[b]	0-10	Authors' assumption
Hourly earnings, employed males age 20–29		
Population total	340,203	2015 ACS
Average hourly earnings	$15.6	2015 ACS
Post-legalization absolute change	($4.85)–($0.42)	Sabia and Nguyen (2016)
Average hours worked per week	37.4	2015 ACS
Average weeks worked per year	51	2015 ACS
Full-time employment, females age 50+ [b]		
Population total	532,394	2015 ACS
Average earnings per year	$49,175	2015 ACS
Percentage employed full time[b]	28.5	2015 ACS
Post-legalization percentage change	1.34–17.48	Nicholas and Maclean (2016)
Hours worked per week, employed males age 50+		
Population total	539,526	Census
Average hourly earnings	$34.1	ACS
Average hours worked per week	41.7	ACS
Average weeks worked per year	50	ACS
Post-legalization percentage change	(0.98)–10.78	Nicholas and Maclean (2016)

Sources: Mathematica's synthesis of estimates from the literature, key stakeholder interviews, and primary and secondary data sources on the impact of legalized adult use of marijuana in Massachusetts.
Note: Values in parentheses reflect negative values.
[a] Values were calculated by the authors based on the data.
[b] FTE = full-time employee, with full-time defined as working more than 35 hours per week.
ACS = American Community Survey; BRFSS = Behavioral Risk Factor Surveillance System; CCC = Cannabis Control Commission; CDC = Centers for Disease Control and Prevention; FARS = Fatality Analysis Reporting System; LCB = Liquor Cannabis Board; MA DOR = Massachusetts Department of Revenue.; MBHS = Marijuana Baseline Health Study; MDOC = Massachusetts Department of Corrections; MDPH = Massachusetts Department of Public Health; NSDUH = National Survey on Drug Use and Health; RMD = registered marijuana dispensary; TEDS = Treatment Episode Data Set; WSIPP = Washington State Institute for Public Policy; YHS = Massachusetts Youth Health Survey; YRBSS = Youth Risk Behavior Surveillance System.

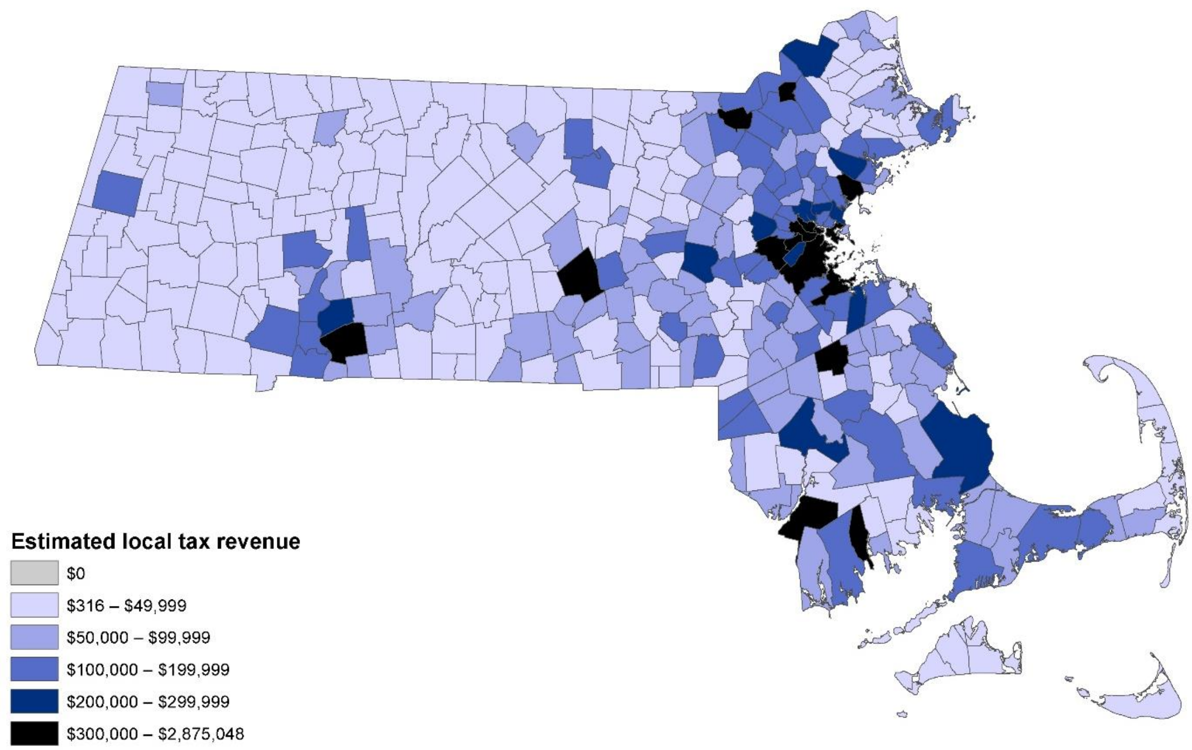
Figure C.1. New Revenue or Savings Estimated Post-Legalization, by Source



Sources: Mathematica's analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimates.

Note: The table displays sources of revenue or savings and excludes measures associated with costs or losses.
CCC = Cannabis Control Commission; MJ = marijuana.

Figure C.2. Estimated Two-Year Local Tax Revenue if Registered Marijuana in all Cities/Towns



Sources: Mathematica's analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimates.

Table C.2. Estimated Two-Year Local Tax Revenue if Registered Marijuana Dispensaries in all Cities/Towns

City or town type	Number of cities or towns	Estimated two-year local tax revenue		
		Median	Minimum	Maximum
Rural (< 100 people/km^2)	29	$3,077	$316	$7,476
Suburban, low density (100–500 people/km^2)	60	$7,713	$1,926	$32,340
Suburban, medium density (501–1,000 people/km^2)	64	$29,375	$9,242	$110,963
Suburban, high density (1,001–10,000 people/km^2)	171	$70,090	$13,076	$369,822
Urban (> 10,000 people/km^2)	27	$258,946	$56,766	$2,875,048

Sources: Mathematica's analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimate

Table C.3. Estimated Two Year Local Tax Revenue for each City or Town

City or town	Cities/towns with an RMD		With RMDs in all towns
	State-level # MJ users	Localized # MJ users	
Abington			$75,951
Acton	$507,245	$501,976	$95,128
Acushnet			$43,548
Adams			$34,745
Agawam			$119,696
Alford			$2,052
Amesbury			$69,236
Amherst	$239,344	$236,474	$157,773
Andover			$138,626
Aquinnah			$1,926
Arlington	$650,422	$643,467	$186,356
Ashburnham			$25,381
Ashby			$13,531
Ashfield			$6,773
Ashland			$71,747
Athol			$48,388
Attleboro	$515,364	$1,294,6	$180,697
Auburn			$68,323
Avon			$17,602
Ayer	$217,917	$215,603	$33,176
Barnstable			$188,234
Barre	$144,385	$142,843	$22,312
Becket			$7,476
Bedford			$58,009
Belchertown			$55,595
Bellingham			$65,061
Belmont			$105,755
Berkley			$26,713
Berlin			$12,384

City or town	Cities/towns with an RMD		With RMDs in all towns
	State-level # MJ users	Localized # MJ users	
Bernardston			$9,144
Beverly			$167,852
Billerica			$178,089
Blackstone			$37,348
Blandford			$4,851
Bolton			$20,461
Boston	$2,875,048	$4,816,1	$2,875,0
Bourne	$83,143	$82,148	$83,143
Boxborough			$21,507
Boxford			$32,757
Boylston			$18,378
Braintree			$143,585
Brewster	$192,128	$189,911	$41,897
Bridgewater	$276,557	$273,457	$129,434
Brimfield			$15,430
Brockton	$435,068	$894,904	$435,068
Brookfield			$14,032
Brookline	$233,498	$309,883	$233,498
Buckland			$7,682
Burlington	$991,873	$981,277	$107,908
Cambridge	$474,261	$413,420	$474,261
Canton	$86,332	$85,346	$86,332
Carlisle			$21,125
Carver			$54,260
Charlemont			$4,672
Charlton	$64,597	$63,862	$54,530
Chatham			$26,304
Chelmsford			$147,046
Chelsea			$159,798
Cheshire			$13,357
Chester	$64,590	$63,872	$6,337
Chesterfield			$4,833
Chicopee	$234,594	$946,729	$234,594
Chilmark			$4,467
Clarksburg			$6,722
Clinton			$57,392
Cohasset			$31,508
Colrain			$7,098
Concord			$80,965
Conway			$7,406
Cummington			$3,473
Dalton			$28,105
Danvers	$204,617	$202,333	$111,665
Dartmouth	$146,365	$82,655	$146,365
Dedham			$98,817
Deerfield	$60,801	$60,111	$21,235
Dennis	$170,113	$168,123	$60,694
Dighton			$29,807
Douglas			$34,794
Dover			$21,918
Dracut			$128,899
Dudley			$47,651
Dunstable			$13,839
Duxbury			$70,371
East			$66,230
East Brookfield			$9,242
East			$66,453
Eastham			$21,389

City or town	Cities/towns with an RMD		With RMDs in all towns
	State-level # MJ users	Localized # MJ users	
Easthampton	$94,629	$93,525	$62,383
Easton			$97,376
Edgartown			$18,002
Egremont			$4,836
Erving			$7,744
Essex			$14,619
Everett			$184,323
Fairhaven	$95,521	$94,415	$67,594
Fall River	$598,643	$1,739,8	$369,822
Falmouth			$133,236
Fitchburg	$272,497	$551,828	$166,944
Florida			$3,009
Foxborough			$67,167
Framingham	$615,046	$288,353	$298,149
Franklin			$124,936
Freetown			$37,255
Gardner	$216,371	$702,916	$84,381
Georgetown	$285,596	$282,577	$33,794
Gill			$7,043
Gloucester	$177,177	$175,121	$121,745
Goshen			$4,323
Gosnold			$316
Grafton	$310,085	$306,819	$74,769
Granby			$24,029
Granville			$6,864
Great Barrington	$68,715	$67,927	$29,321
Greenfield	$177,839	$721,885	$73,490
Groton			$46,187
Groveland			$27,167
Hadley	$34,651	$34,244	$20,715
Halifax			$35,887
Hamilton			$32,159
Hampden			$21,724
Hancock			$3,007
Hanover	$209,486	$207,262	$65,179
Hanson			$48,330
Hardwick			$12,557
Harvard			$27,064
Harwich			$51,760
Hatfield			$12,805
Haverhill			$251,613
Hawley			$1,725
Heath			$3,077
Hingham			$104,370
Hinsdale			$8,710
Holbrook	$299,598	$296,311	$43,544
Holden			$74,199
Holland	$130,809	$129,393	$10,561
Holliston			$58,686
Holyoke	$373,639	$914,954	$165,223
Hopedale			$24,159
Hopkinton			$64,937
Hubbardston			$18,321
Hudson	$396,608	$392,319	$83,066
Hull			$50,121
Huntington			$7,611
Ipswich	$106,752	$105,582	$55,660
Kingston			$60,486

City or town	Cities/towns with an RMD		With RMDs in all towns
	State-level # MJ users	Localized # MJ users	
Lakeville	$97,641	$96,567	$51,709
Lancaster			$33,581
Lanesborough			$12,459
Lawrence			$313,394
Lee	$61,948	$61,236	$24,864
Leicester	$225,355	$222,905	$47,090
Lenox			$21,109
Leominster	$243,144	$874,472	$171,261
Leverett			$8,329
Lexington			$135,482
Leyden			$2,795
Lincoln			$29,611
Littleton			$39,448
Longmeadow			$65,150
Lowell	$1,690,694	$2,589,0	$460,559
Ludlow			$89,500
Lunenburg			$45,485
Lynn	$498,856	$765,457	$366,830
Lynnfield			$49,910
Malden			$258,946
Manchester			$21,401
Mansfield	$368,564	$364,656	$94,800
Marblehead			$81,562
Marion			$23,151
Marlborough			$166,880
Marshfield			$118,373
Mashpee	$501,747	$496,207	$59,104
Mattapoisett			$28,943
Maynard			$44,254
Medfield			$46,519
Medford			$247,455
Medway			$50,216
Melrose			$116,834
Mendon			$24,127
Merrimac	$514,520	$509,036	$26,845
Methuen			$196,644
Middleborough	$125,781	$124,338	$110,963
Middlefield			$2,019
Middleton			$38,676
Milford			$116,405
Millbury	$170,775	$168,911	$55,443
Millis	$610,722	$604,410	$31,070
Millville			$13,076
Milton			$105,128
Monroe			$439
Monson			$36,335
Montague			$35,069
Monterey			$3,696
Montgomery			$3,584
Mount			$674
Nahant			$14,387
Nantucket	$43,840	$43,331	$43,840
Natick			$145,432
Needham	$245,512	$242,867	$113,827
New Ashford			$1,205
New Bedford	$440,200	$1,264,4	$392,760
New Braintree			$4,663
New			$6,268

City or town	Cities/towns with an RMD		With RMDs in all towns
	State-level # MJ users	Localized # MJ users	
New Salem			$4,303
Newbury			$28,121
Newburyport			$72,762
Newton	$552,130	$1,514,9	$369,158
Norfolk			$45,393
North Adams			$57,063
North Andover			$118,211
North			$117,358
North Brookfield			$19,656
North Reading			$64,871
Northampton	$121,055	$521,510	$110,653
Northborough			$60,900
Northbridge			$66,673
Northfield			$12,498
Norton			$80,587
Norwell	$311,404	$308,178	$48,972
Norwood	$280,605	$277,567	$113,341
Oak bluffs			$19,058
Oakham			$7,495
Orange	$125,056	$123,691	$32,109
Orleans			$25,419
Otis			$6,523
Oxford	$222,788	$220,409	$56,386
Palmer			$50,709
Paxton			$20,286
Peabody			$214,906
Pelham			$5,031
Pembroke			$83,915
Pepperell			$49,634
Peru			$3,684
Petersham			$4,940
Phillipston			$7,258
Pittsfield	$416,675	$551,255	$183,360
Plainfield			$2,295
Plainville			$34,132
Plymouth	$415,479	$102,924	$272,645
Plympton			$13,602
Princeton			$14,184
Provincetown	$20,872	$20,610	$13,102
Quincy	$531,229	$1,243,9	$371,084
Randolph	$408,061	$403,573	$131,193
Raynham			$55,836
Reading			$105,602
Rehoboth			$48,945
Revere	$1,251,436	$1,237,8	$232,870
Richmond			$6,400
Rochester			$24,972
Rockland	$354,642	$350,843	$83,074
Rockport			$29,465
Rowe			$1,929
Rowley			$24,553
Royalston			$5,515
Russell			$6,384
Rutland			$33,874
Salem	$681,457	$2,420,7	$175,511
Salisbury			$36,033
Sandisfield			$3,622
Sandwich			$84,908

City or town	Cities/towns with an RMD		With RMDs in all towns
	State-level # MJ users	Localized # MJ users	
Saugus			$113,936
Savoy			$3,298
Scituate			$84,114
Seekonk			$59,858
Sharon	$68,139	$67,399	$68,139
Sheffield			$13,600
Shelburne			$8,381
Sherborn			$17,433
Shirley			$32,066
Shrewsbury	$271,046	$739,408	$148,062
Shutesbury			$7,122
Somerset			$76,402
Somerville	$613,668	$3,028,7	$344,381
South Hadley			$69,147
Southampton			$22,977
Southborough	$193,086	$191,101	$40,083
Southbridge			$69,340
Southwick			$40,192
Spencer			$49,337
Springfield	$988,088	$3,309,6	$625,013
Sterling			$32,321
Stockbridge			$8,845
Stoneham			$93,397
Stoughton			$110,345
Stow			$28,706
Sturbridge	$170,209	$168,378	$38,519
Sudbury			$74,940
Sunderland			$15,841
Sutton			$37,441
Swampscott			$56,766
Swansea			$67,818
Taunton	$356,548	$157,621	$233,927
Templeton			$33,831
Tewksbury			$127,724
Tisbury			$16,969
Tolland			$2,443
Topsfield			$25,570
Townsend			$38,684
Truro			$7,153
Tyngsborough			$50,554
Tyringham			$1,717
Upton			$31,093
Uxbridge			$56,406
Wakefield			$111,036
Wales			$7,841
Walpole			$95,734
Waltham			$272,375
Ware			$37,627
Wareham	$217,119	$217,119	$105,441
Warren			$21,491
Warwick			$3,127
Washington			$2,399
Watertown	$439,564	$434,488	$143,331
Wayland			$55,640
Webster			$70,090
Wellesley			$109,880
Wellfleet			$13,275
Wendell			$3,687

City or town	Cities/towns with an RMD		With RMDs in all towns
	State-level # MJ users	Localized # MJ users	
Wenham			$21,005
West Boylston			$33,548
West			$32,795
West Brookfield			$15,904
West Newbury			$17,567
West Springfield	$118,615	$431,662	$118,615
West			$5,069
West Tisbury	$76,956	$76,108	$10,785
Westborough			$76,302
Westfield	$235,284	$529,505	$173,124
Westford			$95,132
Westhampton			$6,611
Westminster	$46,208	$45,692	$30,727
Weston			$48,419
Westport			$65,801
Westwood			$57,456
Weymouth			$217,369
Whately			$5,863
Whitman			$68,542
Wilbraham			$59,967
Williamsburg			$9,558
Williamstown			$32,340
Wilmington			$96,881
Winchendon			$43,469
Winchester			$90,509
Windsor			$3,785
Winthrop			$78,563
Woburn			$166,385
Worcester	$762,069	$1,298,0	$762,069
Worthington			$4,851
Wrentham			$43,133
Yarmouth			$100,574

Sources: Mathematica’s analysis of impacts of legalized adult use of marijuana in Massachusetts using estimates from the literature, key stakeholder interviews, and primary and secondary data sources. See Appendix C Table C.1 for data sources used to inform these estimates.
MJ = marijuana; RMD = registered marijuana dispensary.

Appendix D

Marijuana Product and Price Characterization

Introduction

Medical marijuana products that are sold in Massachusetts are required to be evaluated according to established laboratory testing protocols (DPH, 2016). Briefly, these protocols describe evaluating dispensed products for contaminants and cannabinoid content, inclusive of evaluating finished (dried) plant material, cannabis resin, and cannabis concentrates. As some of these products (e.g., oils and resins) are tested and later incorporated into marijuana-infused products (MIPs) intended for use as edibles (e.g., capsules, brownies, candy, etc.), or various personal care products (e.g., tinctures, lotions, suppositories, etc.), a marijuana-containing product may undergo multiple rounds of product testing before it is dispensed.

Marijuana products of a similar variety are generally priced according to the cannabinoid content. In August 2017 Registered Marijuana Dispensaries in Massachusetts were asked to complete a voluntary survey of retail marijuana prices to inform the economic and fiscal analyses being conducted as part of the MBHS.

This appendix describes an overview of the cannabinoid content and price of medical marijuana products that were available through the DPH Medical Use of Marijuana Program. As these medical marijuana products were likely to be very similar in composition to the types of products available in adult-use marketplace, an earlier draft of the information provided in this Appendix was used to inform various analyses in the MBHS. As such, a summary of the cannabinoid content and price of retail medical marijuana products available in Massachusetts over the period of May 14, 2015 through December 31, 2018 is included here as Appendix D.

Cannabinoid Content Summary

Marijuana products that are dispensed for medical use in Massachusetts must bear a label that identifies the percentage (by dry weight) of ∆9-tetrahydrocannnabinol (∆9-THC), cannabidiol (CBD), tetrahydrocannabinolic acid (THCa), and cannabidiolic acid (CBDa). Of these cannabinoids, Δ9-THC is the primary psychoactive component and cannabidiol (CBD) is the primary non-psychoactive component of cannabis.

While regulating the sale and use of medical marijuana in Massachusetts, DPH has evaluated over 15,000 laboratory reports, describing over 14,500 medical marijuana products, from thirteen different medical marijuana facilities. These reports have been voluntary submitted to DPH and describe the laboratory testing of flower products (44.6%), MIPs (27.0%), and concentrates, such as resin (3.7%), oils (19.5%), shatter (3.0%), or wax (2.2%). Of these laboratory reports, a total of 12,375 describe an evaluation of cannabinoid profile testing that describes levels of: Δ^9-tetrahydrocannnabinol (Δ^9-THC), cannabidiol (CBD), tetrahydrocannabinolic acid (THCa), and/or cannabidiolic acid (CBDa).

The types of products tested for cannabinoids include flower products (37.2%), concentrates (29.4%), and MIPs (33.3%; see Figure 1). Table 1 describes the cannabinoid testing results for flower, concentrates and MIPs. The cannabinoid Delta (∆)9-THC was detected in 93.3% of flower products, 98.6% of concentrate, and 95.2% of MIPs. The cannabinoid THCa was detected in 99.6% of flower products, 67.2% of concentrates, and 17.0% of MIPs. The cannabinoid CBD was detected in 27.9% of flower products, 56.6% of concentrates, and 33.1% of MIPs. The cannabinoid CBDa was detected in 50.3% of flower products, 53.2% of concentrates, and 7.1% of MIPs.

The cannabinoid content of the available products is shown in Table 2. Of the 4,605 flower samples tested, THCa concentrations were most often between 14-28%. Approximately 5% of flower samples had THCa concentrations greater than 28%. CBDa was rarely detected in flower samples, and never at a concentration greater than 28%. The majority of flower samples (43.6%), had THCa levels between 14 and 21%. Of the 3642 concentrate samples tested, the majority (38.2%) had THC concentrations between 60 and 80%. Approximately, 15.4% of concentrate samples had THC concentrations greater than 80%, while only 0.6% had CBD concentrations greater than 80%.

Retail Price Summary

A summary of the price of retail marijuana products available at 11 of the 12 open and operating RMD locations in August of 2017 is shown in Table 4. Similar products across various RMDs were combined to provide an overview and summary (e.g., same product types) using the RMD retail price survey found in Figure 2. The product's dose of THC (in milligrams) was calculated for any product with a dose presented as a percentage, using the product net weight (i.e., dose percentage multiplied by product net weight).

Reference

Massachusetts Department of Public Health (DPH), 2016. Protocol for sampling and analysis of finished medical marijuana products and marijuana-infused products for Massachusetts registered medical marijuana dispensaries. Available: https://www.mass.gov/service-details/medical-use-of-marijuana-program-product-testing

Table 1. Cannabinoids Present in Retail Marijuana Products (Δ9-THC, THCa, CBD, and CBDa)

Product Type	Products Tested n	Detected n (% tested)	Not Detected n (% tested)
Δ9-THC			
Flower	4605	4295 (93.3%)	310 (6.7%)
Concentrate	3644	3594 (98.6%)	50 (1.4%)
MIPs	4126	3928 (95.2%)	198 (4.8%)
THCa			
Flower	4605	4587 (99.6%)	18 (0.4%)
Concentrate	3644	2447 (67.2%)	1197 (32.8%)
MIPs	4126	700 (17.0%)	3426 (83.0%)
CBD			
Flower	4605	1287 (27.9%)	3318 (72.1%)
Concentrate	3644	2061 (56.6%)	1583 (43.4%)
MIPs	4126	1367 (33.1%)	2759 (66.9%)
CBDa			
Flower	4605	2316 (50.3%)	2289 (49.7%)
Concentrate	3644	1939 (53.2%)	1705 (46.8%)
MIPs	4126	291 (7.1%)	3835 (92.9%)

Table 2. Characterization of Cannabinoid Concentration (weight percent) Levels in Flower and Concentrate Samples

Flower	**THCa < 3%**		**THCa 3 - 7%**		**THCa 7 - 14%**		**THCa 14 - 21%**		**THCa 21 - 28%**		**THCa > 28%**		**Total Samples**
	n	*%*	n	*%*	n	*%*	n	*%*	n	*%*	n	*%*	
	117	*2.50%*	137	*3.00%*	403	*8.80%*	2010	*43.6%*	1701	*36.9%*	237	*5.10%*	4605
	CBDa < 3%		**CBDa 3 - 7%**		**CBDa 7 - 14%**		**CBDa 14 - 21%**		**CBDa 21 - 28%**		**CBDa > 28%**		**Total Samples**
	n	*%*	n	*%*	n	*%*	n	*%*	n	*%*	n	*%*	
	4308	*93.6%*	38	*0.80%*	173	*3.80%*	63	*1.40%*	22	*0.50%*	1	*0.00%*	4605
Concentrate	**THC < 5%**		**THC 5 - 20%**		**THC 20 - 40%**		**THC 40 - 60%**		**THC 60 - 80%**		**THC > 80%**		**Total Samples**
	n	*%*	n	*%*	n	*%*	n	*%*	n	*%*	n	*%*	
	144	*4.00%*	209	*5.70%*	517	*14.2%*	821	*22.5%*	1390	*38.2%*	561	*15.4%*	3642
	**Total THC = [Δ9-THC] + 0.8772*[THCa]*												
	CBD < 5%		**CBD 5 - 20%**		**CBD 20 - 40%**		**CBD 40 - 60%**		**CBD 60 - 80%**		**CBD > 80%**		**Total Samples**
	n	*%*	n	*%*	n	*%*	n	*%*	n	*%*	n	*%*	
	3061	*84%*	279	*7.70%*	135	*3.70%*	89	*2.40%*	55	*1.50%*	23	*0.60%*	3642
	***Total CBD = [CBD] + 0.8772*[CBDa]*												

Table 3. Cannabinoid Content in Retail Marijuana Products

Product Type	25th percentile (% weight)	Median (% weight)	75th percentile (% weight)	95th percentile (% weight)	Maximum (% weight)
Flower	0.2	0.3	0.7	1.9	24.1
Concentrate	3.1	20.5	63.0	87.1	96.9
MIPs	0.1	0.2	0.5	4.5	75.2
Flower	16.3	20.0	23.3	28.0	45.4
Concentrate	13.7	45.5	71.5	84.4	99.8
MIPs	0.0	0.0	0.1	0.9	62.8
Flower	0.1	0.2	0.3	0.6	3.4
Concentrate	0.5	1.0	4.7	49.0	99.0
MIPs	0.1	0.1	0.5	5.8	92.0
Flower	0.1	0.1	0.2	12.5	28.3
Concentrate	0.1	0.2	0.4	12.1	64.2
MIPs	0.0	0.0	0.1	0.6	3.3

Table 4: Summary of Retail Product Prices Provided in RMD Survey

	Product Group	Type	Description	Product Weight	THC Dose	Retail Price
Concentrates	Resin	Rosin	Concentrate for vaporization	0.5-1g	50-85%	$25-$45
	Resin	Keif	Cold pressed bar for vaporization	7g	38%	$100
	Vape Oil	Cartridge	Concentrate oil for vaporization	0.9mL	200-1000mg	$25 - $100
	Wax	Wax	Concentrate for vaporization	1g	900mg	$50
	Vape Oil	Cartridge	Concentrate oil for vaporization	0.25-0.5g	30-90%	$60 - $75
	Shatter	Shatter	Solid concentrate for vaporization	1g	85%	$60
	Oil	Extract or distillate	Extract or distillate for infusion	1g	65-87%	$65-$80
Dried Flower	Pre-roll	Joint/cigar/ cigarette	Intended for smoking	1g	15-35%	$15-$20
	Flower	Finished flower	Various strains	1g	15-35%	$15
	Flower	Finished flower	Various strains	3.5g	15-35%	$50
	Flower	Finished flower	Strain blend	28g	15-30%	$250
	Flower	Finished flower	Various strains	28.4g	15-35%	$250-$350
Edible MIPs	Capsule	Capsule	Infused for ingestion	1-2g	10-25mg	$2.50-$5
	Lozenge	Flavored hard confection	Infused for ingestion	6.5g	10mg	$4-$5
	Chocolate	Chocolate bar/nugget	Infused for ingestion	9-68g	10mg	$4-$10
	Beverage	Lemonade	Infused for ingestion	--	20mg	$10
	Baked Good	Cookie/ muffin	Infused for ingestion	--	10-85mg	$10-$40
	Gummy	Flavored gummy confection	Infused for ingestion	5g	25-50mg	$12-$23
	Chocolate	Chocolate bar/nugget	Infused for ingestion	9-68g	100mg	$25-$30
	Lozenge	Flavored hard confection	Infused for ingestion	6.5g	100mg	$25-$35
	Gummy	Gummy confection	Infused for ingestion	50-100g	100-500mg	$30-$80
	Cooking oil	Grapeseed oil	Infused for ingestion	188g	840mg	$100
Non-Edible MIPs	Suppository	suppository	Rectal/ vaginal use	2g	10mg	$4
	Topical	Lip Balm	Stick for lip application	--	10.15mg	$5
	Suppository	suppository	Rectal/ vaginal use	2g	25mg	$7-$12
	Topical	Salve	Cream for dermal application	28.4g	8-25%	$30-$45
	Topical	Lotion	Cannabis infused topical lotion	112.5g	350-375mg	$30-$60
	Topical	Transdermal patch	Skin application	--	125mg	$40
	Tincture	Tincture	Infused for sublingual application	30mL	500mg	$60-$75

Figure 1. Cannabinoid Testing Results of Retail Marijuana Products for Δ9-THC, THCa, CBD, CBDa through December 31, 2018

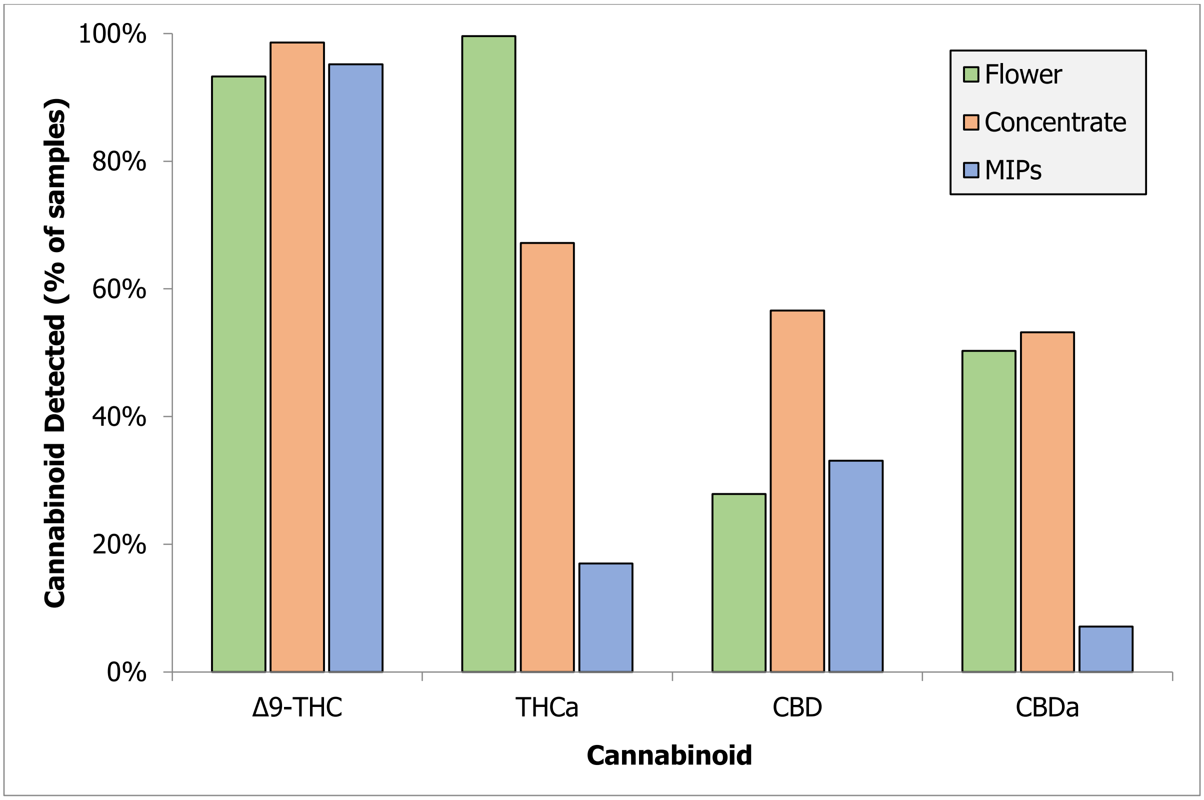


Figure 2: RMD Retail Price Survey*

RMD Name:

Category	Examples	Type	Description	Product Weight	Dose (Potency)	Retail Price
Dried Flower	Finished flower, pre-rolls, "Mini"-Pre-rolls					
Concentrates	Vape pen cartridge, oil, shatter, wax, resins, bubble hash, rosin					
Edible MIPs	Beverage, capsule, lozenge, gummy candy, brownie, cookie, honey, sauces/jams					
Non-Edible MIPs	Tincture, suppository, lotion/salve, massage oil, lip balm, patch, bath oils/salts					

Instructions provided for filling out the above survey:

<u>Category</u>: This column identifies the product-type category (i.e., dried flower, concentrate, edible MIPs, and non-edible MIPs).

Dried Flower: dried leaves and flowers of the female marijuana plant that have been trimmed and dried and include most importantly the inflorescences (i.e., “buds”) that may be used directly (e.g., smoked) as a medical product without further processing.

Concentrate: marijuana product derived by using solvents to extract and concentrate cannabinoid compounds (e.g., oils, pastes, waxes, or solids) or a solid medical marijuana product produced by gathering and compressing the cannabinoid-rich trichomes (i.e., keif) of the marijuana plant (e.g., cannabis resin, “hashish,” “hash,” or “bubble hash”).

Edible Marijuana-Infused Products (edible MIPs): a marijuana-infused product that is to be consumed by eating or drinking.

Non-edible Marijuana-Infused Products (non-edible MIPs): a marijuana-infused product that is to be used through routes other than eating or drinking (i.e., all other uses).

Examples: This column identifies common product-type examples and is not considered an exhaustive list.

Type: This column provides fields to describe further product-type classification. Examples of Types by Category are provided in the Examples column (e.g., finished flower, pre-rolls, “mini"-pre-rolls, etc.).

Description: This column provides fields to include a product description describing characteristics such as appearance, intended route of use, and instructions for use (e.g., suggested serving size).
Product Weight: This column provides fields to include the product weight (e.g., net weight) by unit of sale (e.g., a single serving edible MIP: 100 grams)

Dose/Potency: This column provides fields to include the product cannabinoid dose for each advertised cannabinoid in amounts, expressed as the dry-weight percentages or milligrams of ∆9 - tetrahydrocannnabinol (∆ 9 -THC), cannabidiol (CBD), tetrahydrocannabinolic acid (THCa) and cannabidiolic acid (CBDa) in a medical marijuana product. Amounts of other cannabinoids may be reported, but are not required.

Retail Price: This column provides fields to include the estimated retail price (US dollars) for the specific product described. Itemized prices are most useful but a price range may additionally be provided to capture market variability and other closely related products.