Title Page

**Effects of Marijuana Legalization Policies on Fatal Car Accidents Throughout the Fifty States**

by

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**Abstract**

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University of Pittsburgh, 2020

**Abstract**

Marijuana use is rapidly becoming more prevalent and accepted throughout the United States with repercussions for the public health and medical systems. Though cannabinoids remain a schedule I drug at the federal level, an increasing amount of states are passing more permissive marijuana policies at the state level. Previous research on the effects of marijuana have focused on symptomatic consequences including driving impairment, capacity for addiction, and growing therapeutic use, but studies on the associations between degree of legalization and marijuana use have been historically inconclusive. An original injury epidemiology research report was conducted using the Fatality Analysis Reporting System (FARS) to investigate total fatalities from motor vehicle accidents (MVAs) and marijuana involvement in fatal MVAs by degree of legalization. The results indicate that the odds of positive marijuana test in fatal MVAs increased with decriminalization (OR 1.34, 95% CI 1.29-1.39), medical legalization (OR 1.61, 95% CI 1.58-1.65), and recreational legalization (OR 2.33, 95% CI 2.24-2.42) when compared to illegalization and after controlling for age, sex, race, alcohol use and time in months. A similar result was observed with increasing policy permissiveness being slightly associated with the number of individuals testing positive for marijuana at the medical (0.25 more persons each state per month per 1,000,000, p=0.0001) and recreational (0.44 more persons each state per month per 1,000,000, p<0.0001) legalization stages though decriminalization was not statistically significant (p=0.7703). Deaths from car crashes were also positively associated at the decriminalized (0.12 more persons each state per month per 1,000,000, p<0.0001), medical (0.67 more persons each state per month per 1,000,000, p<0.0001), and recreational (3.31 more persons each state per month per 1,000,000, p<0.0001) legalization stages after controlling for state and time. Though caution should be taken in interpreting results from a biased dataset, there is evidence to suggest that marijuana policy could influence traffic safety as states continue to pass more permissive legislation, requiring an appropriate public health response.

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# Introduction

## Marijuana Epidemiology

The United Nations globally estimates that as of 2015, between 2.7-4.9% of the world’s population have tried marijuana at least once in a recent timeframe, or as many as ten times the amount of people that have tried other internationally regulated drugs such as opiates and cocaine. Prevalence of marijuana use is most often estimated as “consumption within twelve months”, though some studies use intervals as short as 30 days1. Marijuana is one of the most commonly used psychotropic substances in the nation, trailing behind alcohol and eclipsing tobacco in recent years2. The National Center for Drug Abuse Statistics (NCDAS) estimates that 55 million or 16.9% of American adults currently use marijuana, and 3,700 adolescents are exposed to the drug for the first time daily3. Marijuana is used more often by men than women and is most popular between the ages of 18-25. As of July, 2020, 11 states and the District of Columbia have fully legalized marijuana while 27 others have legalized it for medical use.

Cannabis and marijuana are terms often used interchangeably but have crucial differences in the realms of policy and legality. Cannabis or cannabinoid products refer to all the derivatives of the Cannabis plant, of which there are three species: C. sativa, C. indica, and C. ruderalis, though some can be considered subtypes of others. Chemical substances produced by the plant are called cannabinoids, the primary psychoactive component of which is tetrahydrocannabinol (THC) which is a source of contention in medical marijuana policy and recreational marijuana policy (mMP and rMP) within the country.

Marijuana is any cannabis product that contains a significant amount of THC and can be consumed in a variety of methods including as a food, extract, smoking, and vaping. Natural cannabis plants contain anywhere from 10-15% THC and the THC:CBD ratio varies significantly, though studies suggest a ratio of 1:1 has the greatest therapeutic potential for least risk4. Derivatives of cannabis that contain scant amounts of THC (<0.3%) are considered industrial hemp. Cannabinol, which is a cannabinoid, does not have psychoactive properties and can be extracted from marijuana or hemp5. It is used in several pharmaceutical drugs and under certain state laws CBD oil is classified differently to higher THC content products in their medical legalization status. There is no known lethal dose of THC in humans, as no human has been recorded dying from the substance alone. Doses of up to 9000mg/kg were non-lethal in dogs and monkeys, whereas death occurred in rats between THC concentrations of 225-3600mg/kg6.

The U.S. Food and Drug Administration (FDA) has not approved the cannabis plant for medical use or the use of THC and CBD for dietary supplements. It has however approved specific pharmaceutical drugs that use synthetic THC substances like dronabinol (in Marinol and Syndros) and nabilone (in Cesamet). These drugs are indicated for treating nausea, emesis, and anorexia due to conditions like HIV/AIDS and cancer therapies7. Medical marijuana-inclusive drugs have also been used off-label for moderate benefit for other conditions including epilepsy, chronic pain, and headaches. As the purpose of this project is to investigate whether the psychoactive component of marijuana and its availability influences fatal car accidents, states with highly restrictive mMPs allowing only for products with THC content <0.5% will not be classified as having adequate mMPs in place.

Marijuana is currently federally classified as a Schedule I drug with high risk for abuse alongside other substances such as diacetylmorphine (heroin), lysergic acid diethylamide (LSD) and 3,4-methylenedioxymethamphetamine (MDMA / ecstasy)8. This designation has sparked controversy among clinicians and scientists alike over the substance’s debated addictiveness and role as a ‘gateway drug’4. Schedule I drugs are considered to have no medical value, cannot be prescribed, and can only be distributed for federally approved research. Even in states with medical marijuana laws, healthcare providers and physicians cannot prescribe medical marijuana, only recommend its use. Patients that have a qualifying condition often need to acquire it through specific dispensaries or authorized entities that can manufacture and distribute the substance9.

The effects of marijuana vary greatly by pharmacokinetics. Composition of tetrahydrocannabinol (THC) and cannabidiol (CBD), the route of administration (oral, smoking, vaporized, extract), and the dosing value all result in effects that can deviate based on the individual. Adverse events resulting from the drug are typically related to its THC component, with a total daily dose equivalent recommended not to exceed 30mg/day or in conjunction with CBD to “avoid psychoactive sequelae and development of tolerance”10.

There is a growing body of evidence that supports the medical indication of marijuana in neurologic, psychiatric, and pain-related disorders11-12 as well as headache, migraine, and to assist in opioid detoxification13. In contrast, chronic marijuana use has also been associated with poorer educational outcomes, early school-leaving, addiction, depression, cognitive impairment, and cannabis-related car accidents14-15.

## Impact on Operating Vehicles

For drivers who are involved in motor vehicle accidents (MVAs) and / or are reported as drug-impaired, cannabinoids are the most common psychoactive substance discovered in the blood16 and are associated with an three to seven times increase in culpability than non-impaired drivers17-20. Current literature demonstrates a direct association between cannabis and impaired driving ability19,21-23. Some studies have affirmed that THC selectively impacts certain driving tasks worse than others, and that users tend to compensate by driving more slowly but control diminishes for more complex tasks23. Highly automated activities such as self-correcting road tracking were more affected than conscious control24. Combining alcohol and THC products has been shown to increase the odds of driver error additively rather than synergistically compared to their constituents alone22.

Though a wealth of evidence supports the deterioration of driving ability with increasing cannabis consumption, preventing driving under the influence of cannabis (DUIC) proves a difficult task considering public perception. A majority of surveyed DUIC drivers believed cannabis provided minimal driving risk, that risks could be compensated by experience, and indicated that they were likely to reoffend for DUIC in the future19. However, epidemiological findings and their experimental counterparts have sometimes disagreed over the degree of cannabis effects on operating motor vehicles25. A large case-control study conducted by the National Highway Traffic Safety Administration found no significant increased crash risk attributable to cannabis after controlling for drivers’ age, gender, race, and presence of alcohol.26,20.

## Marijuana Policies and Law

Marijuana legislation was first enacted in 1937 with the Marijuana Tax Act, with enormous variation in policy within the states and over the decades since. One of the most important consolidations of federal law concerning the substance was the Controlled Substance Act of 1970 as part of President Nixon’s “War on Drugs’ campaign. This classified marijuana as a schedule I drug with no redeemable medical benefit, and though the statute has been revised multiple times up until the year 2017 it has made it difficult to study the effects of marijuana use in the United States population in relation to its increasing consumption27, particularly for medical purposes.

While public perception throughout the U.S. is shifting towards being receptive of legalization28, long-term consequences of marijuana consumption especially among chronic users is poorly understood and its risks potentially downplayed by advocates. ‘Home-grown’ marijuana that has become more prevalent with legalization laws poses perhaps the most significant risk, having higher THC concentrations that have been associated with increased psychoactive states such as paranoia, psychosis, and aggression, especially in individuals with pre-existing mental disorders29. Psychosis risks have been found to be greater in chronic users that begin in adolescence, but marijuana legalization has been more associated with adult use than adolescent use30. Research within the past two decades suggests that DUIC approximately doubles the risk of having a motor vehicle accident (MVA) and, in adolescents, doubles the risk of early drop-out from school as well as contributing to cognitive impairments and other illicit drug use into adulthood15. Legalization has also shown a decrease in perceived harmfulness and increase in marijuana use among teenagers31.

Investigating the diverse sociocultural factors that precipitate marijuana use requires understanding the convoluted policies that define its use. Policies vary over time and between states, which rarely transition from an illegal state to recreational state but instead have overlapped laws with increasing degree of permissiveness throughout the years. Most current states that have legalized marijuana use had first decriminalized certain possession offenses, followed by allowing for medical marijuana exemptions, and then settling on legalization. As a result of this recent experimentation with legalization and the degrees of complexity surrounding decriminalization and patient medical access laws, both public perception and epidemiological research on widespread marijuana effects on society can be obfuscated. There is a dearth of literature on the effects of marijuana pre- and post-legalization, and existing literature with slow or inconclusive findings which can create the illusion of harmlessness for the drug. Previous evaluations of legislation on marijuana and its effects have been primarily based on prevalence rates27, which noticeably do not encompass the difference between casual and chronic users and do not contain information on route of administration and dosage of the drug.

For the purposes of this report, marijuana policies are classified according to their four levels of legal definition. Prohibition outlaws the use of marijuana entirely, including actions such as possession, cultivation, sale, and distribution. Decriminalization is the reduction in penalties associated for cannabis offenses, typically civil instead of criminal penalties for smaller charges and was first championed by the Shaffer Commission in 1972. Currently, mMPs are state-based laws that increase access of cannabinoids for medical purposes only despite the federal government maintaining marijuana as a schedule I drug with no therapeutic value. In some cases, mMPs are seen as a veneer for legalization and rMPs, which is the final level of policy that removes criminal and monetary penalties and allows cannabis for recreational purposes32.

The Insurance Institute for Highway Safety has created a table summarizing current marijuana laws by state as of August 202033, which can be viewed in Appendix A Table 1.

## Legislation and Public Health Significance

The heterogeneity of policies is a great concern for both practical and research implications28. The policies themselves, the population at the time which they address, the products they license, the state they are enacted in, the time period they are signed in comparison to when they take effect, and multiple other metrics can complicate outcomes and introduce lag effects that make establishing correlation and even causation difficult.

Early studies on immediate effects of change in marijuana policy in the 1970s-1980s were inconsistent, especially in regard to decriminalization of marijuana. Consumption and prevalence patterns examined during this time period used crude measures which potentially contributed to the variance in methods and results34, especially when attempting to compare to other states which retained more severe penalties. Though decriminalization had not appeared to influence marijuana use rates, many states including California found significant cost savings in the criminal justice system as a result35. It is impossible to have a discourse on marijuana legalization, particularly early decriminalization policies, without the political factors of rising state budgetary costs, arrests, misdemeanor marijuana crimes and incarceration of nonviolent drug offenders36.

Marijuana legalization is not only tied to the justice system but the sphere of public health. One of the more immediate impacts of cannabis use can be tied to traffic safety and emergency department visits. Between the years of 1973 and 1978 twelve states had decriminalized the possession of marijuana and during this time, metropolitan hospital emergency room data found a significant decrease in visits related to drug involvement of drugs other than marijuana, while episodes related to marijuana increased36.

However, describing an association between marijuana legalization and marijuana outcomes through time is nuanced. Though Colorado voters approved recreational marijuana in November of 2012, retail sales did not begin until 2014. The delay in licensing manufacturers, creating dispensaries, and distributing marijuana to the public is difficult to quantify by state and by legislative act. As Colorado was also one of the first states to legalize recreational marijuana, marijuana tourism also became an acknowledged side effect of the process. A study of urban hospitals under the Colorado Hospital Association between the years of 2011 and 2014 found that in-state resident emergency department (ED) visits did not significantly change from 2011-2014, but out-of-state resident marijuana-related ED visits increased from 78 per 100,000 in 2011 to 163 per 100,000 visits in 2014, which marked the first year of retail sales38.

Similarly, a study of a regional level-I trauma center found that approximately 60% of MVA admissions tested positive for alcohol or drugs in the blood, with more testing positive for drug use than alcohol34. Prior to its discontinuation, the Drug Abuse Warning Network (DAWN) estimated approximately 456,000 marijuana-related emergency department visits within the year 2011, an increase from previous years39. However, marijuana overdose itself was not necessary to be categorized as a marijuana-related visit.

With even limited conclusive evidence of cannabis-related outcomes in the criminal justice, education and youth, medical, and public health fields, marijuana use and policy has become a key concern for both lawmakers and the public in recent years. As states continue to push towards legalization, the short and long-term effects of increasing marijuana use will become more prevalent and establishing a greater understanding of how it impacts the population is necessary to adequately prepare for the impending stressors it may place.

# Objectives

This essay examines as an independent variable four levels of marijuana policy (where marijuana is illegal, decriminalized only, medically legalized, and recreationally legalized) and what impact, if any, they have on the following three objectives including one sub-objective:

1. Proportion of individuals involved in fatal crashes that tested positive for marijuana
   1. Proportion of drivers in fatal crashes that tested positive for marijuana by policy level
2. Number of individuals involved in fatal crashes that tested positive for marijuana
3. Number of deaths from fatal crashes

# Methods

## FARS Database

Data for this report was obtained from the National Highway Traffic Safety Administration’s (NHTSA) Fatality Analysis Reporting System (FARS) for the most recent fifteen years of complete data available (2004 to 2018). The final data consisted of N=1,280,256 total individuals involved in a car accident that lead to at least one fatality across the fifty states excluding the subgroup for the District of Columbia and U.S. territories such as the Virgin Islands and Puerto Rico. Total fatalities by crash ranged from 1 to 23 individuals, with 59.92% (n=767,087) of all involved individuals being drivers in-transport, 32.13% (n=411,332) being passengers in-transport, and the remaining 7.95% (n=101,837) of individuals being occupants of a vehicle not-in-transport, non-motorists such as pedestrians and cyclists, those in buildings, others, and unknowns.

Numerous coding and referencing changes have been applied to the FARS database since its initiation in 1975. Some data sets were not available until a certain year onwards, some variables from previous datasets had been moved, renamed, or integrated into other variables as a result, and some attribute codes had been modified over time to increase clarity but for the most part were able to be retroactively applied to data from older years. There were a total of 44 variables used in the final data set which were compiled from four files per year (ACCIDENT and PERSON files which have been used since 1975, DRIMPAIR and NMIMPAIR which were in use from 2010 and onwards, and DRUGS, which moved some data from the PERSON file into a separate entity as of 2018). Information regarding these changes was obtained from the *Fatality Analysis Reporting System (FARS) Analytical User’s Manual, 1975-2018.*

While police and state-level reporting and designations of drug use may vary, any individuals involved in a fatal car accident was considered to have been under the influence of marijuana if they were coded as testing positive for delta-9, hashish oil, hashish, marijuana, Marinol, or tetrahydrocannabinol (THC).

## Other Sources

The degree of marijuana legalization among the fifty states was classified into three true or false variables: decriminalization, medical marijuana use permitted, and recreational legalization. This allows for easier coding of dummy variables in SAS as well as the ability to account for overlaps in degree of legalization, primarily with decriminalization being able to occur before and after medical marijuana legalization enactment. When combined they create one overall variable for legalization with the four stages as discussed in the introduction: illegal across the board, decriminalized only, medical legalization, and recreational legalization, with the latter categories overriding the earlier ones.

As specific marijuana policies vary by state and within state by cities and municipalities, a state is only considered to fall under the four categories of legalization if they have the appropriate legislation passed at the state level. Additionally, a state is marked by the corresponding bill’s month of enactment instead of the date it was approved, as the delay between signing the legislation into law and when it becomes effective can span several months which can contribute to erroneous data. Legislation data was obtained from the National Conference of State Legislatures, Insurance Institute for Highway Safety and ballot research by state40,33.

The smallest unit of time used in this report is months to preserve the most amount of data regarding the stage of legalization throughout the year within the states. However, census population estimates required for adjustment are only created annually and predicated on July 1st of every year. For this reason, all months within a year for each state will use the estimated population of that state for that year for all adjustment calculations. Population data was obtained from the United States Census Bureau’s 2000-2010 and 2010-19 Population Intercensal Estimates41.

## Statistical Analyses

The statistical software used for analysis of this project was SAS. The FARS datasets provided by NHTSA were separated into files by year and as some files, codes, and variables changed throughout the data time span, modification was required to standardize the data if it had not already been processed retroactively. For the outcome variables, fatality counts remained consistent however the drug testing indicators and drug test results were moved into their own file in 2018, requiring additional processing to match the corresponding data of the previous fourteen years. The only files used for this analysis were those pertaining to the overall summary of accident data, the individual characteristics of those involved in the accidents, and any information regarding impairment and drug use.

Three outcomes of interest were evaluated; the proportion of individuals involved in fatal crashes that test positive for marijuana (with the sub-category of the proportion of drivers in fatal crashes that test positive for marijuana), the number of individuals that test positive for marijuana use, and the number of deaths that occurred in the dataset. The number of deaths and number of individuals with a positive test were investigated first as a dichotomous variable and then as a frequency count which was further adjusted by population levels within the state during the year. The primary independent variable was level of legalization which contained four categories from most restrictive to least restrictive marijuana legislation: illegal, decriminalized only, medical legalization, and recreational legalization. States that had decriminalized marijuana but later passed medical or recreational marijuana laws assumed the higher designation.

Categorical data was analyzed with chi-squared tests for descriptive statistics, logistic regression for odds of marijuana involvement, and Poisson regression for rates of positive tests and deaths. The smallest unit of data was by month and state increments in order to maximize data availability for policy implementation. Due to this, frequencies were considerably small and adjusting for lower than 1,000,000 members of the population can render the data difficult to interpret. Neither the crude frequency counts of marijuana involvement and deaths nor the adjusted per 1,000,000 counts of both variables were found to have a normal distribution. Logistic regression controlled for age, sex, race, alcohol involvement, and time measured in months, while Poisson regression controlled for state and time measured in months.

The timing of legalization laws throughout the fifty states varied significantly in the time period of the analysis: some states have enacted more MPs before the start of the period (2004) than others, or had policies that did not change throughout the fifteen year duration (most commonly with states that have prohibited the use of marijuana throughout the data period). As a result, the reference category for each state (if not illegalization) was set to the lowest degree of legalization during the data period.

# Results

Descriptive statistics show that the frequency of fatalities in motor vehicle transportation varied throughout the 2004-2018 year period, between a range of 10,044 deaths. The fatality count was highest in 2004 with 43,462 deaths, which then trended downward meaningfully over the years to its lowest in 2011 at 32,584 deaths. In the years following there has been a substantial increase and in 2018 there have been 42,628 fatalities reported. Overall, presence of marijuana and associated cannabinoids was only reported in 3.59% (n=45,972) of all individuals that were involved in a fatal car crash within the years of 2004-2018 in the U.S. and 76.91% (n=35,359) of the users were the driver in the accident. Among users, 78.503% (n=35,872) died during the motor vehicle accident, while 21.97% (n=10,100) survived (OR of marijuana users dying compared to non-users is 4.56, CI 4.46 – 4.65). Demographic information can be seen in Appendix A Table 2 for the characteristics of all individuals involved a fatal crash and all persons who died in the crash. Of all individuals involved in a fatal crash, 65% are reported as male and 33% as female. Among those under the influence of cannabinoids, 81% are male and 19% are female.

The results of the logistic regression analysis for combined states demonstrated a clear association between increasing legalization of marijuana and the likeliness of an individual involved in a fatal car accident to have tested positive in a drug test for cannabinoids. Compared to settings where marijuana is illegal, the odds of testing positive for marijuana in both participants and drivers of fatal car crashes increases consecutively with more permissive policy as seen in Table 1 after controlling for age, sex, race, alcohol involvement and time in months.

Table 1. Odds Ratios of Testing Positive for Marijuana by Policy Level

|  |  |  |  |
| --- | --- | --- | --- |
| Level of Policy | Odds Ratio | Lower 95% Confidence Interval | Upper 95% Confidence Interval |
| All Individuals Involved in Fatal Crashes | | | |
| Illegal | 1.00 | -- | -- |
| Decriminalized Only | 1.34 | 1.29 | 1.39 |
| Medical Legalization | 1.61 | 1.58 | 1.65 |
| Recreational Legalization | 2.33 | 2.24 | 2.42 |
| Drivers in Fatal Crashes | | | |
| Illegal | 1.00 | -- | -- |
| Decriminalized Only | 1.28 | 1.22 | 1.34 |
| Medical Legalization | 1.63 | 1.59 | 1.67 |
| Recreational Legalization | 2.23 | 2.13 | 2.34 |

The number of individuals who test positive for marijuana use as well as the number of MVA deaths at the national level are described in Table 2. Mean individuals refers to the average number of people in one state over the course of one month that either test positive for marijuana or die while the state is under the respective policy designation. Additionally, population adjustment occurs at the state level for that month. All results are statistically significant except for testing positive for marijuana between illegal and decriminalized states, a trend which continues at the state level and posits decriminalization policy as having the least, if any, effect on marijuana involvement and car crash deaths throughout the dataset. Generally, the average number of people who test positive for marijuana and who die in car crashes within the years of 2004-2018 increase as policy becomes more permissive except for fatalities during decriminalization, which decreases slightly.

Table 2. Marijuana Involvement and Death by Policy Level Per State Per Month

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Individuals in MVAs That Tested Positive for Marijuana Involvement | | | | |
| Level of Policy | Mean Individuals | P-value | Mean Individuals per 1,000,000 | P-value |
| Illegal | 3.55 | <.0001 | 0.91 | 0.0053 |
| Decriminalized Only | 3.6 | <.0001 | 0.97 | 0.7703 |
| Medical Legalization | 4.19 | <.0001 | 1.16 | 0.0001 |
| Recreational Legalization | 5.08 | <.0001 | 1.35 | <.0001 |
| Deaths from MVAs | | | | |
| Level of Policy | Mean Individuals | P-value | Mean Individuals per 1,000,000 | P-value |
| Illegal | 39.64 | <.0001 | 10.24 | <.0001 |
| Decriminalized Only | 38.00 | <.0001 | 10.36 | <.0001 |
| Medical Legalization | 41.33 | <.0001 | 10.91 | <.0001 |
| Recreational Legalization | 50.01 | <.0001 | 13.55 | <.0001 |

Additionally, both logistic and Poisson regression analysis was conducted within each individual state to calculate the odds of a positive marijuana test (significant results in Appendix A Table 3), the number of deaths (Appendix A Table 4) and the number of positive tests (Appendix A Table 5). However, these results differed highly in statistical significance, direction, and magnitude by state: Alaska for example saw the odds of marijuana involvement in fatal MVAs increase by 1.61 (p=0.0384, 95% CI 1.03-2.54) during the recreational legalization period as opposed to medical legalization, while Oregon saw the odds decrease from the same transition in policy by 0.53 (p=0.004, 95% CI 0.34-0.82). The odds of positive marijuana tests and number of deaths by state and by policy tended to have statistically significant results, while 35/88 changes in policy across all states were non-significant for number of positive tests. This discrepancy may be explained by the more limited availability of data by policy at the individual state level, exacerbating the already low incidence of positive tests, especially in comparison to the relatively more common car crash fatalities outcome. However, considering the highly varied confidence intervals, p-values, and imbalance of time under specific MPs or even the lack of some MPs throughout the 2004-2018 period, state-level data were less reliable. Overall, the results at the individual state level were highly irregular though most experienced an increase in fatalities from car crashes as marijuana policy became more permissive.

Examples of some of the distribution of total deaths stratified by marijuana legalization and why they should be considered carefully can be seen in Appendix B Figures 1 and 2. For California (Appendix B Figure 1), which represents a state that only experienced two types of policy in the data period (2004-2018), the average number of deaths from car crashes began to rise even before the transition to recreational legalization. For Massachusetts (Appendix B Figure 2), which experienced four types of policy change, the sudden rise in fatalities in the last few months of the data period cannot be easily explained by the only two years the state had made recreational marijuana legal; furthermore, experiencing only a few years under each level of policy may not yield accurate results due to lag effects.

# Discussion

The research questions posed in this project were developed to address the gaps in knowledge between traffic safety regarding marijuana use and the change in degree of marijuana legalization throughout the nation. Specifically, the objectives were aimed at investigating whether increasing legalization of marijuana was associated with marijuana involvement in fatal car crashes and total deaths from fatal car crashes.

The results of this report suggest a positive association for all three outcomes: the odds of positive marijuana tests, number of positive marijuana tests and number of deaths in fatal car crashes increase with more permissive marijuana legalization. Recreational legalization has the greatest effect size for all outcomes and decriminalization has the smallest effect size, with one non-significant result at the combined state level for number of positive tests during decriminalization in comparison to positive tests during the illegal period. However, a series of factors suggest that special caution should be taken in interpreting these findings, particularly the outcome of total overall deaths from fatal car accidents by marijuana legalization. Important considerations include the often limited availability of legalization data by state, the recent trend of an increase overall in total car crash deaths over time, the contrasting directional coefficients of outcomes in different states, as well as numerous potential biases occurring throughout the original dataset.

Controlling for alcohol involvement and time reduced the magnitude of results by a greater margin than controlling for sex, race, and age. Time was defined in units of months and had relatively different outcomes than measuring by year, stressing the importance of including the effective policy date in the analysis. In the overall results for the combined states, the proportion of positive tests and average number of deaths in car crashes were significantly higher for times under mMP and rMP stages. The lack of significant association during decriminalization for the odds of a positive test and for multiple outcomes at the individual state level is consistent with previous research and lends greater confidence to overall modelling.

It is important to point out that these results pertain to fatal crashes only, and the findings may differ when considering less severe crashes. Crashes in the FARS database receive extensive investigation and heightened attention to impairment related issues. Non-fatal MVAs, in contrast, have by nature of the incident a limited amount of information available as they are less likely to be reported to the authorities. It is unknown whether there is a difference in representation of marijuana users among those who are involved in fatal MVAs against those who are not. Though cannabis use has been associated with some increased aggression and recklessness, these characteristics are not as widely recognized as those in other drugs such as alcohol which predisposes drivers to an increase in car crashes.

While there is extensive investigation of fatal crashes, field information gathering is prone to error, drug reporting has changed over time, and drug testing policy has changed over time. The training and vigilance of law enforcement at the state level, drug testing and drug results can also be impacted as marijuana awareness and legalization increases42. Reporting issues can also influence the covariates of the analysis such as alcohol-impaired driving, which for example was either not reported or reported as unknown in nearly half the sample (Appendix A Table 2). NHTSA detailed the inconsistencies of current literature surrounding marijuana-impaired driving, the lack of standardized testing, and the comparisons to alcohol and limitations of the FARS dataset in their report to Congress in 201735. Additionally, NHTSA’s case-control crash risk study in 2015 was the first large-scale study to directly compare marijuana use in car crashes, and found that after adjusting for age, race, gender and alcohol involvement, the odds ratio disparity between marijuana users and non-marijuana users became insignificant43.

The intricacies of marijuana policy pose numerous concerns for the validity of data. While policy is defined at the state level and by month of effective start date, no deliberation was given to specific clauses relating to eligibility, licensing, distribution, possession, and cultivation of cannabis. Some policy variables are more susceptible to lag (chronic consumption patterns, establishment of dispensaries and cannabis-related businesses) than others (possession and transportation amounts, ability to grow the plant at home). Medical marijuana programs can restrict eligibility depending on specific diseases or conditions44 and in states that require annual registration have been found to both lower consumption prevalence rates among youth, young adult, and lower program admission rates than states without equivalent stipulations; similarly, policy addressing home cultivation and accessibility of legal dispensaries are associated with increases in recreational and heavy use45.

Other specifications of policy that can impact cannabis use patterns include the ability of states to recognize out-of-state patients for medical marijuana programs, the range of weight amounts and degree of lessened penalization that cannabis is legalized for in decriminalization laws, the amount, reach, and timeliness of authorizing dispensaries after bill approval, the date that retail sales begin, the composition percentage of THC in cannabinoid products allowed, partial decriminalization (such as for first offense) laws and potential spill-over effects onto neighboring states.

Knowing that MPs are both complex and have potentially delayed effects on traffic safety, the analysis suffers additionally from states that have limited data or a narrow timeframe in which they were classified under having either illegal, decriminalization, medical marijuana, or recreationally legal MPs. Missouri for example, which had passed decriminalization laws in January 2017 and medical marijuana laws in November of 2018, has a limited number of months of data for these classifications as opposed to nearly thirteen years of data where marijuana was entirely illegal. As a result, even though the medical legalization deaths within the state were considered statistically significant, it only differs by 0.4 deaths per month per 1,000,000 from the illegalization period; for positive marijuana tests, the result is non-significant.

Future studies investigating the relationship between marijuana policy and consumption trends should deliberate on specific law allowances as well as the potential bias of marijuana use in a population that must gain majority approval to pass cannabis-related laws. A state with residents that view marijuana use favorably but without political means to put cannabis laws on the ballot may have different use patterns by the time medical or recreational marijuana is legalized compared to a state unreceptive to cannabis.

Finally, it is important to consider not only seen factors that may influence marijuana legalization on its involvement in fatal car crashes and overall deaths, but unseen factors that may directly and indirectly affect the outcomes of study. After bearing in mind the biases of the dataset used and the complexity of legalization policy, the trends of traffic accidents in general over time should be examined more closely. Deaths from fatal car crashes can stem from inclement weather, need of the public to travel more distance, risk taking behaviors among drivers, road infrastructure, eyesight, advancements in technology and educational awareness among an enormous variety of other causes46. Without proper understanding of these factors, investigating and interpreting traffic safety outcomes will continue to be elusive, but the apparent reemergence of fatal car deaths and its historical importance as an obstacle to public health will need to be addressed.

* + - * 1. Tables

Appendix A Table 1. Marijuana Laws by State (August 2020)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| State | Type of law | Age restrictions | Possession limits | Retail recreational sales allowed |
| Alabama | limited medical; effective July 1, 2014 | none | specified cannabis product that contains no more than 3 percent THC |  |
| Alaska | medical; effective June 1, 1999 | none | no more than 1 ounce |  |
| recreational; effective February 24, 2015 | if under age 21, not allowed to purchase, possess, or use | no more than 1 ounce | Oct-16 |
| Arizona | medical | none | no more than 2.5 ounces |  |
| Arkansas | medical; effective November 9, 2016 | if under age 21, cannot smoke medical marijuana | no more than 2.5 ounces |  |
| California | medical; effective November 6, 1996 | none | no more than 8 ounces unless a greater amount is deemed medically necessary |  |
| recreational; effective November 9, 2016 | if under age 21, not allowed to purchase, possess, or use | no more than 28.5 grams of cannabis not in the form of concentrated cannabis and no more than 8 grams of concentrated cannabis | 1-Jan-18 |
| Colorado | medical; effective June 1, 2001 | if under age 18, cannot smoke medical marijuana when on school grounds, on a school bus, or at a school-sponsored event | no more than 2 ounces unless a greater amount is deemed medically necessary |  |
| recreational; effective December 10, 2012 | if under age 21, not allowed to purchase, possess, or use | no more than 1 ounce | 1-Jan-14 |
| Connecticut  **Appendix A Table 1 Continued** | medical; effective October 1, 2012 | if under age 21, cannot smoke medical marijuana | not to exceed an amount reasonably necessary to ensure the uninterrupted availability for 1 month |  |
| Delaware | medical; effective July 1, 2011 | if under age 18, may use only medical marijuana oil and only for certain debilitating conditions and symptoms | no more than 6 ounces |  |
| District of Columbia | medical; effective in 2009 | none | no more than 4 ounces |  |
| recreational; effective February 26, 2015 | if under age 21, not allowed to purchase, possess, or use | no more than 2 ounces | not allowed |
| Florida | medical; effective March 25, 2016 | none | 70-day supply or 4 ounces in a form for smoking unless a greater amount is deemed medically necessary |  |
| Georgia | limited medical; April 16, 2015 | none | no more than 20 fluid ounces of specified cannabis product that contains no more than 5 percent THC |  |
| Hawaii | medical; effective June 14, 2000 | none | no more than 4 ounces |  |
| Idaho | no law | n/a | n/a |  |
| Illinois | medical; effective January 1, 2014 | if under age 18, may have ID card only for seizures or as provided by administrative rule; if under age 21, may use only medical cannabis-infused products | no more than 2.5 ounces unless a greater amount is deemed medically necessary; for registered qualifying patients who are at least 21 years old, 5 plants that are more than 5 inches tall and any cannabis produced by those plants so long as any amount in excess of 30 grams of raw cannabis is secure within the residence |  |
| recreational; effective January 1, 2020 | if under age 21, not allowed to purchase, possess, or use | no more than 30 ounces of cannabis flower, 500 milligrams of THC contained in cannabis-infused product, and 5 grams of cannabis concentration | 1-Jan-20 |
| Indiana | limited medical; April 26, 2017 | none | specified cannabis product that contains no more than 0.3 percent THC |  |
| Iowa | limited medical; effective July 1, 2014 | none | no more than 4.5 grams in a 90-day period unless a greater amount is deemed medically necessary |  |
| Kansas  **Appendix A Table 1 Continued** | limited medical; effective July 1, 2019 | none | specified cannabis product that contains no more than 5 percent THC relative to the cannabidiol concentration in the preparation |  |
| Kentucky | limited medical; effective April 10, 2014 | none | specified cannabis product obtained pursuant to a written order of a physician practicing at a hospital or associated clinic affiliated with a Kentucky public university having a college or school of medicine, derived from industrial hemp, or approved as a prescription by the FDA |  |
| Louisiana | limited medical | none | 1 month supply; one dose shall contain no more than 10 milligrams of THC |  |
| Maine | medical; December 22, 1999 | none | up to 2.5 ounces |  |
| recreational; effective January 30, 2017 | if under age 21, not allowed to purchase, possess, or use | up to 2.5 ounces | expected in March 2020 |
| Maryland | medical; effective June 1, 2011 | none | no more than 30-day supply unless a greater amount is deemed medically necessary |  |
| Massachusetts | medical; effective January 1, 2013 | none | no more than 60-day supply, up to 10 ounces or as determined by the cannabis control commission |  |
| recreational; effective December 15, 2016 | if under age 21, not allowed to purchase, possess, or use | no more than 1 ounce; within the person's primary residence, no more than 10 ounces | 20-Nov-18 |
| Michigan | medical; effective December 4, 2008 | none | no more than 2.5 ounces |  |
| recreational; effective December 6, 2018 | if under age 21, not allowed to purchase, possess, or use | no more than 2.5 ounces; within the person's residence, no more than 10 ounces | 1-Dec-19 |
| Minnesota | medical; effective May 30, 2014 | none | no more than 30-day supply |  |
| Mississippi | limited medical; effective April 17, 2014 | none | specified cannabis product provided by the National Center for Natural Products Research at the University of Mississippi and dispensed by the Department of Pharmacy Services at the University of Mississippi Medical Center |  |
| Missouri | medical; effective December 6, 2018 | if under age 18 and not emancipated, may not have an ID card, purchase, or possess marijuana | purchase no more than 30-day supply, which can be limited to no less than 4 ounces of dried, unprocessed marijuana, unless a greater amount is deemed medically necessary; possess at least 60-day supply, although qualifying patients who can cultivate marijuana may possess up to 90-day supply |  |
| Montana  **Appendix A Table 1 Continued** | medical; effective November 2, 2004 | if under age 18, cannot smoke medical marijuana and can only used marijuana-infused products | up to 1 ounce |  |
| Nebraska | no law | n/a | n/a |  |
| Nevada | medical; effective by late November or early December 2000 | none | no more than 2.5 ounces in any 14-day period unless a greater amount is deemed medically necessary |  |
| recreational; effective January 1, 2017 | if under age 21, not allowed to purchase, possess, or use | no more than 1 ounce | 1-Jul-17 |
| New Hampshire | medical; effective July 23, 2013 | none | no more than 2 ounces |  |
| New Jersey | medical; effective October 1, 2010 | none | no more than 3 ounces in a 30-day period unless a greater amount is deemed medically necessary |  |
| New Mexico | medical; effective July 1, 2007 | none | 3-month supply |  |
| New York | medical; effective July 5, 2014 | none | no more than 30-day supply; individual dose may not contain more than 10 milligrams of THC |  |
| North Carolina | limited medical; effective July 13, 2014 | none | specified cannabis product that contains no more than 0.9 percent THC |  |
| North Dakota | medical; effective April 17, 2017 | if under age 19, may use only "pediatric medical marijuana", which contains no more than 6 percent THC | no more than 3 ounces unless an amount up to 7.5 ounces is deemed medically necessary |  |
| Ohio | medical; effective September 8, 2016 | none | no more than 90-day supply |  |
| Oklahoma | medical; effective July 26, 2018 | none | no more than 72 ounces of edible marijuana, 3 ounces of marijuana on the person, 8 ounces of marijuana in the residence, and 1 ounce of concentrated marijuana |  |
| Oregon  **Appendix A Table 1 Continued** | medical; effective December 3, 1998 | if under age 18, cannot produce medical marijuana | no more than 24 ounces |  |
| recreational; effective December 4, 2014 | if under age 21, not allowed to purchase, possess, or use | no more than 8 ounces of usable marijuana, 16 ounces of cannabinoid products in solid form, 72 ounces of cannabinoid products in liquid form, and 16 ounces of cannabinoid concentrates | 1-Oct-15 |
| Pennsylvania | medical; effective May 17, 2016 | none | no more than 30-day supply |  |
| Rhode Island | medical; effective July 1, 2006 | none | no more than 2.5 ounces and an amount of wet marijuana as determined by the departments of health and business regulation |  |
| South Carolina | limited medical; effective June 2, 2014 | none | specified cannabis product that contains no more than 0.9 percent THC |  |
| South Dakota | no law | n/a | n/a |  |
| Tennessee | limited medical; effective May 16, 2014 | none | specified cannabis product that contains less than 0.9 percent THC |  |
| Texas | limited medical; effective June 1, 2015 | none | specified cannabis product that contains no more than 0.5 percent THC |  |
| Utah | medical; effective May 8, 2018 | if under age 18, may only qualify for a provisional patient card | legal dosage limit sufficient to provide 30 days of treatment and may not exceed 113 grams of unprocessed marijuana or an amount of cannabis product that contains no more than 20 grams of total composite THC |  |
| Vermont | medical; effective July 1, 2004 | none | no more than 2 ounces |  |
| recreational; effective July 1, 2018 | if under age 21, not allowed to purchase, possess, or use | no more than 1 ounce | not allowed |
| Virginia | limited medical; effective February 26, 2015 | none | specified cannabis product that contains no more than 5 percent THC |  |
| Washington | medical; December 3, 1998 | if under age 18, may not grow marijuana plants or purchase marijuana-infused products, useable marijuana, or marijuana concentrates from a marijuana retailer | no more than 48 ounces of marijuana-infused product in solid form, 3 ounces of useable marijuana, 216 ounces of marijuana-infused product in liquid form, or 21 grams of marijuana concentrates unless a greater amount is deemed medically necessary, |  |
| recreational; effective December 6, 2012 | if under age 21, not allowed to purchase, possess, or use | no more than 1 ounce of useable marijuana, 16 ounces of marijuana-infused product in solid form; 72 ounces of marijuana-infused product in liquid form, and 7 grams of marijuana concentrate | 8-Jul-14 |
| West Virginia | medical; effective July 1, 2019 | none | no more than 30-day supply |  |
| Wisconsin | limited medical; effective April 17, 2014 | none | specified cannabis product in a form without a psychoactive effect |  |
| Wyoming | limited medical; effective July 1, 2015 | none | specified cannabis product that contains less than 0.3 percent THC |  |

**Appendix A Table 1 Continued**

Appendix A Table 2. Demographics of Individuals Involved in Car Crashes

|  |  |  |
| --- | --- | --- |
| Variable | Category | Frequency (Percent) |
| Individuals in All Crashes (n=1,280,256) | | |
| Age |  |  |
|  | 0-12 | 82002 (6.41%) |
|  | 13-17 | 81520 (6.37%) |
|  | 18-25 | 262567 (20.51%) |
|  | 26-35 | 214711 (16.77%) |
|  | 36-45 | 179364 (14.01%) |
|  | 46-55 | 171875 (13.43%) |
|  | 56-65 | 124602 (9.73%) |
|  | 65+ | 163615 (12.78%) |
| Sex |  |  |
|  | Male | 837071 (65.38%) |
|  | Female | 423902 (33.11%) |
| Marijuana Involvement |  |  |
|  | Yes | 45972 (3.59%) |
|  | No | 1234284 (96.41%) |
| Alcohol Involvement |  |  |
|  | Yes | 135713 (10.6%) |
|  | No | 515887 (40.3%) |
|  | Not Reported | 498706 (38.95%) |
|  | Reported as Unknown | 129950 (10.15%) |
| Individuals in Fatal Crashes (n=569,905) | | |
| Age |  |  |
|  | 0-12 | 16489 (2.94%) |
|  | 13-17 | 25604 (4.56%) |
|  | 18-25 | 111300 (19.84%) |
|  | 26-35 | 93136 (16.60%) |
|  | 36-45 | 79090 (14.10%) |
|  | 46-55 | 82983 (14.79%) |
|  | 56-65 | 64583 (11.51%) |
|  | 65+ | 87720 (15.64%) |
| Sex |  |  |
|  | Male | 395424 (70.5%) |
|  | Female | 165206 (29.45%) |
|  | Unknown or Other | 275 (0.04%) |
| Marijuana Involvement |  |  |
|  | No | 525033 (93.6%) |
|  | Yes | 35872 (6.4%) |
| Alcohol Involvement |  |  |
|  | Yes | 91390 (16.29%) |
|  | No | 193911 (34.57%) |
|  | Not Reported | 175604 (31.31%) |
|  | Reported as Unknown | 100000 (17.83%) |
| Race |  |  |
|  | White | 408496 (72.8%) |
|  | Black | 68113 (12.1%) |
|  | American Indian (includes Alaska Native) | 9277 (1.7%) |
|  | Asian | 8131 (1.4%) |
|  | Multiple Races | 1401 (0.2%) |
|  | Pacific Islander | 4262 (0.8%) |
|  | Unknown or Other | 61225 (10.9%) |

**Appendix A Table 2 Continued**

**Appendix Table 1 Continued**

Appendix A Table 3. Significant Odds Ratios of Marijuana Involvement by State

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| State | Policy Comparison | Odds Ratio | Lower 95% Confidence Interval | Upper 95% Confidence Interval | P-value |
| Alaska | Recreational Legalization vs Medical Legalization | 1.61 | 1.03 | 2.54 | 0.038 |
| Connecticut | Medical Legalization vs Decriminalized Only | 0.16 | 0.04 | 0.66 | 0.011 |
| Connecticut | Illegal vs Decriminalized Only | 0.21 | 0.05 | 0.89 | 0.034 |
| Florida | Medical Legalization vs Illegal | 0.81 | 0.71 | 0.92 | 0.001 |
| Louisiana | Medical Legalization vs Illegal | 0.50 | 0.38 | 0.65 | <0.0001 |
| Massachusetts | Medical Legalization vs Decriminalized Only | 1.47 | 1.05 | 2.07 | 0.0264 |
| Michigan | Recreational Legalization vs Illegal | 0.51 | 0.39 | 0.67 | <0.0001 |
| Michigan | Medical Legalization vs Illegal | 0.56 | 0.44 | 0.72 | <0.0001 |
| Oklahoma | Medical Legalization vs Illegal | 0.60 | 0.39 | 0.92 | 0.020 |
| Oregon | Recreational Legalization vs Medical Legalization | 0.53 | 0.34 | 0.82 | 0.004 |

Appendix A Table 4. Deaths in Car Crashes per Month by State and Policy Level Adjusted per 1,000,000

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| State | Policy Level | Deaths | P-value\* | State | Policy Level | Deaths | P-value\* |
| Alabama | Illegal | 17.2282 | <.0001 | Missouri | Decriminalized Only | 17.7164 | <.0001 |
| Alaska | Medical Legalization | 7.7881 | <.0001 | Missouri | Medical Legalization | 17.2716 | <.0001 |
| Alaska | Recreational Legalization | 11.8054 | <.0001 | Montana | Illegal | 16.9616 | <.0001 |
| Arizona | Illegal | 13.1031 | <.0001 | Montana | Medical Legalization | 18.5712 | <.0001 |
| Arizona | Medical Legalization | 12.0313 | <.0001 | Nebraska | Decriminalized Only | 10.3855 | <.0001 |
| Arkansas | Illegal | 16.6308 | <.0001 | Nevada | Medical Legalization | 9.471 | <.0001 |
| Arkansas | Medical Legalization | 17.1561 | <.0001 | Nevada | Recreational Legalization | 13.3362 | <.0001 |
| California | Medical Legalization | 7.466 | <.0001 | New Hampshire | Illegal | 7.3518 | <.0001 |
| California | Recreational Legalization | 10.3538 | <.0001 | New Hampshire | Medical Legalization | 9.6953 | <.0001 |
| Colorado | Medical Legalization | 8.4394 | <.0001 | New Jersey | Illegal | 6.6637 | <.0001 |
| Colorado | Recreational Legalization | 9.949 | <.0001 | New Jersey | Medical Legalization | 5.5899 | <.0001 |
| Connecticut | Illegal | 6.7813 | <.0001 | New Mexico | Illegal | 21.1129 | <.0001 |
| Connecticut | Decriminalized Only | 5.8169 | <.0001 | New Mexico | Medical Legalization | 14.8906 | <.0001 |
| Connecticut | Medical Legalization | 6.6288 | <.0001 | New York | Illegal | 5.0858 | <.0001 |
| Delaware | Illegal | 11.3817 | <.0001 | New York | Medical Legalization | 5.3793 | <.0001 |
| Delaware | Medical Legalization | 11.019 | <.0001 | North Carolina | Illegal | 12.3275 | <.0001 |
| Florida | Illegal | 12.0695 | <.0001 | North Dakota | Illegal | 15.6262 | <.0001 |
| Florida | Medical Legalization | 16.147 | <.0001 | North Dakota | Medical Legalization | 14.162 | <.0001 |
| Georgia | Illegal | 12.3732 | <.0001 | Ohio | Decriminalized Only | 8.0278 | <.0001 |
| Hawaii | Medical Legalization | 7.2928 | <.0001 | Ohio | Medical Legalization | 11.5922 | <.0001 |
| Idaho | Illegal | 12.2585 | <.0001 | Oklahoma | Illegal | 15.7489 | <.0001 |
| Illinois | Illegal | 6.6491 | <.0001 | Oklahoma | Medical Legalization | 19.364 | <.0001 |
| Illinois | Medical Legalization | 7.9816 | <.0001 | Oregon | Medical Legalization | 8.0477 | <.0001 |
| Indiana | Illegal | 10.6858 | <.0001 | Oregon | Recreational Legalization | 13.2238 | <.0001 |
| Iowa | Illegal | 10.2217 | <.0001 | Pennsylvania | Illegal | 8.5987 | <.0001 |
| Kansas | Illegal | 12.1011 | <.0001 | Pennsylvania | Medical Legalization | 9.932 | <.0001 |
| Kentucky | Illegal | 15.8228 | <.0001 | Rhode Island | Illegal | 6.1742 | <.0001 |
| Louisiana | Illegal | 14.2944 | <.0001 | Rhode Island | Medical Legalization | 5.3361 | <.0001 |
| Louisiana | Medical Legalization | 18.3227 | <.0001 | South Carolina | Illegal | 17.077 | <.0001 |
| Maine | Medical Legalization | 9.8215 | <.0001 | South Dakota | Illegal | 14.4332 | <.0001 |
| Maine | Recreational Legalization | 12.5655 | <.0001 | Tennessee | Illegal | 14.3094 | <.0001 |
| Maryland | Illegal | 7.343 | <.0001 | Texas | Illegal | 11.4404 | <.0001 |
| Maryland | Medical Legalization | 9.2981 | <.0001 | Utah | Illegal | 8.0099 | <.0001 |
| Massachusetts | Illegal | 5.9169 | <.0001 | Utah | Medical Legalization | 4.4879 | 0.0035 |
| Massachusetts | Decriminalized Only | 4.6263 | <.0001 | Vermont | Illegal | 6.6028 | <.0001 |
| Massachusetts | Medical Legalization | 4.2281 | <.0001 | Vermont | Medical Legalization | 9.3799 | <.0001 |
| Massachusetts | Recreational Legalization | 5.0778 | <.0001 | Vermont | Recreational Legalization | 16.6773 | <.0001 |
| Michigan | Illegal | 10.5254 | <.0001 | Virginia | Illegal | 8.6222 | <.0001 |
| Michigan | Medical Legalization | 7.6477 | <.0001 | Washington | Medical Legalization | 6.2905 | <.0001 |
| Michigan | Recreational Legalization | 8.8059 | <.0001 | Washington | Recreational Legalization | 7.0118 | <.0001 |
| Minnesota | Decriminalized Only | 6.3191 | <.0001 | West Virginia | Illegal | 15.2915 | <.0001 |
| Minnesota | Medical Legalization | 7.732 | <.0001 | West Virginia | Medical Legalization | 21.2393 | <.0001 |
| Mississippi | Decriminalized Only | 20.4965 | <.0001 | Wisconsin | Illegal | 9.4016 | <.0001 |
| Missouri | Illegal | 12.5247 | <.0001 | Wyoming | Illegal | 21.1952 | <.0001 |

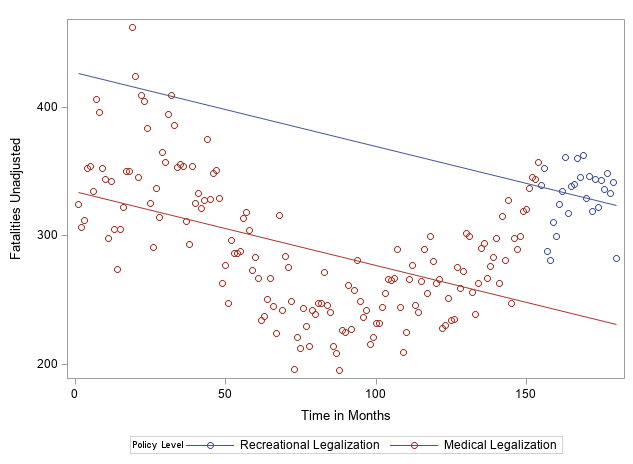
**Appendix A Table 4 Continued**

Appendix A Table 5. Marijuana Involvement in Car Crashes per Month by State and Policy Level Adjusted per 1,000,000

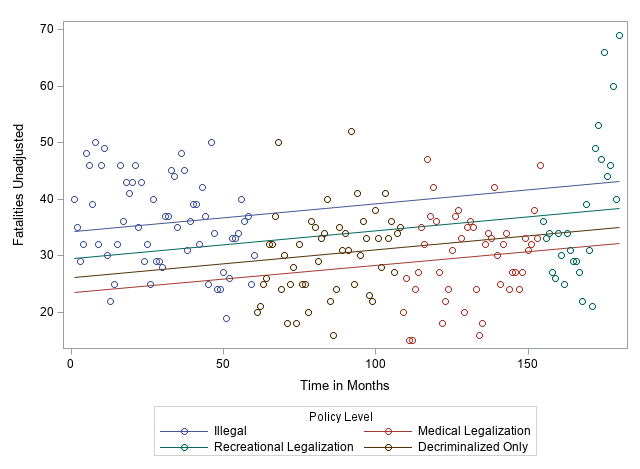
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| --- | --- | --- | --- | --- | --- | --- | --- |
| State | Policy Level | Positive Tests | P-value | State | Policy Level | Positive Tests | P-value |
| Alabama | Illegal | 1.1428 | 0.1195 | Missouri | Decriminalized Only | 1.9431 | 0.0002 |
| Alaska | Medical Legalization | 2.7628 | <.0001 | Missouri | Medical Legalization | 1.6048 | 0.3554 |
| Alaska | Recreational Legalization | 3.3883 | <.0001 | Montana | Illegal | 2.8833 | <.0001 |
| Arizona | Illegal | 0.8546 | 0.4766 | Montana | Medical Legalization | 3.5318 | <.0001 |
| Arizona | Medical Legalization | 0.6186 | 0.0093 | Nebraska | Decriminalized Only | 0.8097 | 0.0617 |
| Arkansas | Illegal | 1.5826 | <.0001 | Nevada | Medical Legalization | 1.4137 | <.0001 |
| Arkansas | Medical Legalization | 1.6697 | 0.1589 | Nevada | Recreational Legalization | 2.1657 | <.0001 |
| California | Medical Legalization | 0.9088 | 0.2714 | New Hampshire | Illegal | 1.7421 | <.0001 |
| California | Recreational Legalization | 1.2631 | 0.2788 | New Hampshire | Medical Legalization | 2.1968 | <.0001 |
| Colorado | Medical Legalization | 1.071 | 0.6137 | New Jersey | Illegal | 0.6966 | 0.1673 |
| Colorado | Recreational Legalization | 1.1849 | 0.3279 | New Jersey | Medical Legalization | 0.5222 | 0.0006 |
| Connecticut | Illegal | 1.3699 | 0.5172 | New Mexico | Illegal | 2.7046 | 0.0296 |
| Connecticut | Decriminalized Only | 0.3948 | 0.4893 | New Mexico | Medical Legalization | 1.5971 | <.0001 |
| Connecticut | Medical Legalization | 0.6291 | 0.0788 | New York | Illegal | 0.5371 | <.0001 |
| Delaware | Illegal | 1.9176 | 0.0023 | New York | Medical Legalization | 0.5603 | 0.0309 |
| Delaware | Medical Legalization | 1.901 | <.0001 | North Carolina | Illegal | 0.1201 | 0.0063 |
| Florida | Illegal | 0.6113 | <.0001 | North Dakota | Illegal | 1.9779 | <.0001 |
| Florida | Medical Legalization | 1.0071 | 0.9783 | North Dakota | Medical Legalization | 1.4071 | 0.2913 |
| Georgia | Illegal | 0.7001 | 0.0001 | Ohio | Decriminalized Only | 1.1362 | 0.0904 |
| Hawaii | Medical Legalization | 1.7518 | <.0001 | Ohio | Medical Legalization | 1.7977 | 0.0021 |
| Idaho | Illegal | 1.2079 | 0.028 | Oklahoma | Illegal | 0.4614 | <.0001 |
| Illinois | Illegal | 0.8954 | 0.4426 | Oklahoma | Medical Legalization | 0.9448 | 0.8917 |
| Illinois | Medical Legalization | 0.8453 | 0.4033 | Oregon | Medical Legalization | 0.4682 | <.0001 |
| Indiana | Illegal | 0.8786 | 0.1101 | Oregon | Recreational Legalization | 0.8026 | 0.4974 |
| Iowa | Illegal | 0.6104 | <.0001 | Pennsylvania | Illegal | 0.5762 | <.0001 |
| Kansas | Illegal | 0.7878 | 0.0079 | Pennsylvania | Medical Legalization | 0.7339 | 0.2586 |
| Kentucky | Illegal | 1.2404 | 0.0034 | Rhode Island | Illegal | 1.5223 | 0.2575 |
| Louisiana | Illegal | 0.6305 | 0.0004 | Rhode Island | Medical Legalization | 1.6031 | <.0001 |
| Louisiana | Medical Legalization | 1.5365 | 0.0475 | South Carolina | Illegal | 2.1293 | <.0001 |
| Maine | Medical Legalization | 0.9485 | 0.8115 | South Dakota | Illegal | 1.807 | <.0001 |
| Maine | Recreational Legalization | 0.6476 | 0.3666 | Tennessee | Illegal | 1.0311 | 0.6849 |
| Maryland | Illegal | 0.2038 | 0.0078 | Texas | Illegal | 0.5541 | <.0001 |
| Maryland | Medical Legalization | 0.178 | 0.2476 | Utah | Illegal | 0.7092 | 0.0019 |
| Massachusetts | Illegal | 1.0993 | 0.8564 | Utah | Medical Legalization | 0.385 | 0.4514 |
| Massachusetts | Decriminalized Only | 0.7752 | 0.2419 | Vermont | Illegal | 2.3486 | 0.0677 |
| Massachusetts | Medical Legalization | 0.457 | 0.0134 | Vermont | Medical Legalization | 2.7285 | <.0001 |
| Massachusetts | Recreational Legalization | 0.4967 | 0.2096 | Vermont | Recreational Legalization | 3.1222 | <.0001 |
| Michigan | Illegal | 0.571 | 0.0662 | Virginia | Illegal | 0.4849 | <.0001 |
| Michigan | Medical Legalization | 0.6941 | 0.012 | Washington | Medical Legalization | 1.319 | 0.0209 |
| Michigan | Recreational Legalization | 0.9171 | 0.8094 | Washington | Recreational Legalization | 1.4759 | 0.0137 |
| Minnesota | Decriminalized Only | 0.4409 | <.0001 | West Virginia | Illegal | 1.3962 | <.0001 |
| Minnesota | Medical Legalization | 0.5906 | 0.0701 | West Virginia | Medical Legalization | 1.7936 | 0.0539 |
| Mississippi | Decriminalized Only | 0.8831 | 0.3028 | Wisconsin | Illegal | 0.9796 | 0.8006 |
| Missouri | Illegal | 1.508 | <.0001 | Wyoming | Illegal | 3.3191 | <.0001 |

**Appendix A Table 5 Continued**

* + - * 1. Figures



Appendix B Figure 1. Crash Deaths in California from 2004-2018 by Marijuana Policy



Appendix B Figure 2. Crash Deaths in Massachusetts from 2004-2018 by Marijuana Policy

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