The Vermont Legislative Research Service

Contact: Professor Anthony Gierzynski
517 Old Mill, Burlington, VT 05405-4110, Telephone (802) 656-7973, Fax (802) 656-0758
http://www.uvm.edu/~vlrs/ • E-mail: Anthony.Gierzynski@uvm.edu

Marijuana Legalization and Traffic Safety

The RAND Corporation Report on marijuana legalization commissioned by Governor Shumlin describes traffic accidents as one possible acute health risk associated with marijuana use.[1] The purpose of this report is to further examine the issue of traffic safety as it relates to marijuana use. To date, it does not appear that one can conclude that marijuana legalization in Washington and Colorado has resulted in a significant increase in the number of traffic fatalities. While it is clear marijuana use can impair drivers, available crash data reveals few changes to any major indices of traffic safety in Colorado and Washington following legalization of marijuana.

The Vermont Context

As of July 2013, possession of less than one ounce of marijuana by individuals 21 and older is considered a civil violation in Vermont; individuals convicted of possession may be fined up to $200 for their first offense.[2] No changes to DUI law have coincided with decriminalization. Current statutes prohibit operating any vehicle on a highway when under the influence of any drug.[3] Medical marijuana has been legal in Vermont since 2004. Yearly trends in total traffic fatalities have not changed since the decriminalization of marijuana in 2013.

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[1] Caulkins, Jonathan P., Beau Kilmer, Mark A. R. Kleiman, Robert J. MacCoun, Gregory Midgette, Pat Oglesby, Rosalie Liccardo Pacula and Peter H. Reuter. "Considering Marijuana Legalization: Insights for Vermont and Other Jurisdictions," Santa Monica, CA: RAND Corporation, 2015, http://www.rand.org/pubs/research_reports/RR864.html.

[2] Vermont Statutes Online, Title 18: Health: Chapter 084: Possession And Control Of Regulated Drugs: Subchapter 001: Regulated Drugs: Section 4230, "Marijuana," Vermont General Assembly, accessed February 18, 2016, http://legislature.vermont.gov/statutes/section/18/084/04230.

[3] Vermont Statutes Online, Title 23: Motor Vehicles: Chapter 013: Operation of Vehicles: Subchapter 013: Drunken Driving: Section 1201, "Operating vehicle under the influence of intoxicating liquor or other substance," Vermont General Assembly, accessed February 18, 2016, http://legislature.vermont.gov/statutes/section/23/013/01201.

Legalization and Traffic Safety Measures in Other States

Colorado

Colorado voters passed an initiative ballot measure to add Amendment 64, regulating and legalizing the personal use of marijuana to the state constitution on November 6th, 2012. Possession of marijuana and growing marijuana for personal use by persons 21 and older became legal on December 10th, 2012.[4] Commercial sales began on January 1st, 2014.

The Colorado law prohibiting driving while impaired was amended following legalization to establish a *per se* limit—similar to the alcohol limit of .08 BAC—of five nanograms of active THC per milliliter of blood. What we refer to as **active tetrahydrocannabinol (THC)** in this report is **delta-9 THC**, which is the psychoactive chemical that causes intoxication; **inactive or carboxy-THC** is just the metabolite that can stay in a user's system for up to 30 days after use without causing intoxication.[5] Drivers with a higher concentration of active THC in their blood may be prosecuted for driving while ability impaired.[6]

Washington

Possession of usable marijuana and marijuana-infused products in small quantities by individuals 21 and older became legal on December 6th, 2012; commercial sale of marijuana began in July 2014.[7] As in Colorado, DUI laws in Washington were amended to establish a *per se* limit for cannabis intoxication at 5 nanograms of active delta-9- THC per milliliter of whole blood (5 ng/mL). An individual may be guilty of driving under the influence if chemical analysis indicates a THC concentration of 5.00 ng/mL or higher within two hours after driving.[8]

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[4]Colorado Revised Statutes, Article 18: Miscellaneous: Section 16: "Personal Use And Regulation Of Marijuana," General Assembly of the State of Colorado, accessed February 18, 2016, http://www.lexisnexis.com/hottopics/colorado/?app=00075&view=full&interface=1&docinfo=off&searchtype=get&search=Colo.+Const.+Art.+XVIII%2C+Section+16.

[5] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014," October 2015, accessed on February 18, 2015, http://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2015/10/Driver-Toxicology-Testing-and-the-Involvement-of-Marijuana-in-Fatal-Crashes_REVFeb2016.pdf.

[6]Colorado Revised Statutes, Title 42: Vehicles and Traffic: Article 4: Regulation of Vehicles and Traffic: Part 13: "Alcohol and Drug Offenses," General Assembly of the State of Colorado, accessed February 18, 2016, http://www.lexisnexis.com/hottopics/colorado/?app=00075&view=full&interface=1&docinfo=off&searchtype=get&search=C.R.S.+42-4-1301.

[7] Revised Code of Washington, Title 69: Foods, Drugs, Cosmetics, and Poisons: Chapter 50: Uniform Controlled Substances Act: Section 4-13, "Possession of controlled substances-Penalty-Possession of useable marijuana, marijuana concentrates, or marijuana-infused products," Washington State Legislature, accessed February 18, 2016, http://app.leg.wa.gov/RCW/default.aspx?cite=69.50.4013.

[8] Revised Code of Washington, Title 46: Motor Vehicles: Chapter 61: Rules of the Road: Section 502, "Driving under the influence," Washington State Legislature, accessed February 18, 2016, http://apps.leg.wa.gov/rcw/default.aspx?cite=46.61.502.

Alaska

Possession of up to one ounce of marijuana, in addition to personal cultivation of up to six plants, became legal for persons 21 and older on February 24, 2015.[9] Alaska's Marijuana Control Board will begin issuing licenses for retail sale in June 2016.[10]

State law classifies marijuana as a Schedule VIA controlled substance; legalization of marijuana has not changed laws prohibiting driving while under the influence of these substances.[11] In contrast to Washington and Oregon, Alaska has not passed legislation establishing a per se limit for marijuana intoxication.[12]

Oregon

Possession of limited amounts of recreational marijuana for personal use, in addition to personal cultivation on private property, by persons 21 and older became legal on July 1, 2015.[13] The Oregon Liquor Control Commission (OLCC) began accepting applications for commercial sales licenses on January 4, 2016. The OLCC expects to license retailers by fall 2016.[14]

As in Alaska, Oregon laws prohibiting driving while under the influence of intoxicants have not been amended following the legalization of marijuana. Oregon law does not set a per se limit for active THC.[15]

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[9] Alaska Statutes, Title 17: Food and Drugs: Chapter 38: The Regulation Of Marijuana: Section 010, "Purpose and findings," Alaska State Legislature, accessed February 18, 2016, http://www.legis.state.ak.us/basis/statutes.asp#17.38.010.

[10] Alaska Department of Commerce, Community, and Economic Development, Alcohol & Marijuana Control Office, "Marijuana Initiative FAQs," accessed February 18, 2016, https://www.commerce.alaska.gov/web/amco/MarijuanaInitiativeFAQs.aspx.

[11] Alaska Statutes, Title 11: Criminal Law: Chapter 71: Controlled Substances: Section 010, "Misconduct involving a controlled substance in the first degree," Alaska State Legislature, accessed February 18, 2016, http://www.legis.state.ak.us/basis/statutes.asp#11.71.010.

[12] Alaska Statutes, Title 28: Motor Vehicles: Chapter 35: Offenses and Accidents: Section 030, "Operating a vehicle, aircraft, or watercraft while under the influence of an alcoholic beverage, inhalant, or controlled substance," Alaska State Legislature, accessed February 18, 2016, http://www.legis.state.ak.us/basis/statutes.asp#28.35.029.

[13] Oregon Revised Statutes, Volume 12: Drugs and Alcohol, Fire Protection, Natural Resources: Chapter 475B: Cannabis Regulation; Section 005, "Purposes of ORS 475B.010 to 475B.395," Driving Under the Influence of Intoxicants, Oregon State Legislature, accessed Feburary 18, 2016, https://www.oregonlegislature.gov/bills_laws/ors/ors475B.html.

[14] Oregon Liquor Control Commission, "Frequently Asked Questions," accessed February 18, 2016, https://www.oregon.gov/olcc/marijuana/pages/frequently-asked-questions.aspx#Policy.

[15] Oregon Revised Statutes, Volume 17: Utilities, Vehicle Code, Watercraft, Aviation, Constitutions: Chapter 813: Driving Under the Influence of Intoxicants, Oregon State Legislature, accessed Feburary 18, 2016, https://www.oregonlegislature.gov/bills_laws/ors/ors813.html.

Summary of Major Findings for Other States

Washington and Colorado have amended statutes to set *per se* limits for driving under the influence of cannabis at 5 ng/mL of active THC in a person's blood. Oregon and Alaska have not altered their existing DUI laws; these states also have yet to license retails sales of marijuana. Colorado, Alaska and Oregon allow for personal cultivation of marijuana on private property.

Testing and Enforcement

Testing

Testing for marijuana through blood or urine tests can be problematic for many reasons. For example, urinalysis tests for the inactive carboxy-THC metabolite that can remain in a heavy user's system for 30 days leading to an inaccurate measurement/indication of impairment.[16] Blood testing detects the active delta-9 THC, but even testing for delta-9 THC can lead to falsely declaring a subject intoxicated. In testimony to the Vermont State Senate Committee on Health and Welfare, Malik Burnett wrote, "the acute effects of smoked cannabis last only 3-4 hours, while the active ingredients in the plant are stored in the body's fat cells for much longer, causing experienced marijuana users to test positive even when they are not impaired."[17] In addition to the inability of these tests to determine current intoxication, THC can affect users in very different ways. A connection between observed THC blood concentrations and intoxication has not been established.[18] There is a lack of agreement over per se limits in the scientific community; limits range from 5 ng/ml to 25 ng/ml worldwide. Burnett posits that the best way to avoid wrongful conviction of unimpaired users is to rely on multiple factors to measure intoxication, such as officer observation in conjunction with blood and oral fluid tests.[19]

An alternative method of detecting marijuana use is oral fluid testing. Oral fluid (saliva) testing is currently used in the European Union and Australia in partnership with field sobriety examinations in order to assess drug impairment. [20,] Additionally, roadside oral

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[16] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014," October 2015, accessed on February 18, 2015, http://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2015/10/Driver-Toxicology-Testing-and-the-Involvement-of-Marijuana-in-Fatal-Crashes_REVFeb2016.pdf.

[17] Vermont General Assembly, Senate Committee on Health and Welfare, "Malik Burnett: Written Testimony," accessed on February 18, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/Senate%20Health%20and%20Welfare/Marijuana/W~Malik%20Burnett~Written%20Testimony~1-20-2016.pdf.

[18] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014."

[19] Vermont General Assembly, Senate Health and Welfare Committee, "Malik Burnett: Written Testimony," accessed on February 18, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/Senate%20Health%20and%20Welfare/Marijuana/W~Malik%20Burnett~Written%20Testimony~1-20-2016.pdf.

[20] NMS Labs, "Draeger Safety Diagnostics, INC. Oral Fluid FAQ," October 2011, accessed on February 18, 2016, http://www.nmslabs.com/uploads/PDF/Oral%20Fluid%20FAQ.pdf.

fluid testing has been piloted in Florida, Texas, California, and Virginia.[21] Oral fluid testing, unlike blood testing, has the advantage of not requiring a medical professional to draw a sample. Like other methods, oral fluid tests cannot specify an individual's level of impairment.[22] A study of oral fluid testing in Vermont conducted by The Center for Forensic Science Research and Education found that oral fluid testing accurately detected marijuana use, but the report's authors suggest oral fluid is most effective as a corroborative measure used along with standard field sobriety tests.[23]

Government agencies in states which have legalized recreational marijuana have sought to deter impaired driving through a variety of public outreach and awareness campaigns. Research suggests the acute effects of smoking marijuana lasts between 3-4 hours,[24] while some laboratory experiments indicate certain driving-related capacities (such as critical tracking or concentrated attention) may be diminished between 8-10 hours.[25] Alaska's Department of Health and Social Services (DHSS) cautions that while drivers may feel safe to drive 2 to 3 hours after using marijuana, impairment may last much longer.[26] The DHSS also notes that using alcohol and marijuana together results in greater driving impairment than using either substance alone.

Drug Recognition Experts

In addition to chemical testing for drug intoxication, Drug Recognition Experts (DREs) may assess drivers for marijuana impairment. Police officers may become DRE-certified through the National Highway Traffic Safety Administration's Drug Evaluation and Classification Program. Trainees are required to complete a minimum of 112 hours of classroom

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[21] Vermont General Assembly, Senate Health and Welfare Committee, "Malik Burnett: Written Testimony," accessed on February 18, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/Senate%20Health%20and%20Welfare/Marijuana/W~Malik%20Burnett~Written%20Testimony~1-20-2016.pdf.

[22] Vermont General Assembly, House Committee on Judiciary, "H.560: Final Report- Vermont Oral Fluid Drug Testing Study 2015," accessed on February 23, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/House%20Judiciary/Bills/H.560/W~Lieutenant%20John%20Flanagan~Final%20Report-%20Vermont%20Oral%20Fluid%20DrugTesting%20Study%202015~1-6-2016.pdf.

[23] Vermont General Assembly, House Committee on Judiciary, "H.560: Final Report- Vermont Oral Fluid Drug Testing Study 2015," accessed on February 23, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/House%20Judiciary/Bills/H.560/W~Lieutenant%20John%20Flanagan~Final%20Report-%20Vermont%20Oral%20Fluid%20DrugTesting%20Study%202015~1-6-2016.pdf.

[24] Vermont General Assembly, Senate Committee on Health and Welfare, "Malik Burnett: Written Testimony," accessed on February 18, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/Senate%20Health%20and%20Welfare/Marijuana/W~Malik%20Burnett~Written%20Testimony~1-20-2016.pdf.

[25] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014," October 2015, accessed on February 18, 2015, http://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2015/10/Driver-Toxicology-Testing-and-the-Involvement-of-Marijuana-in-Fatal-Crashes_REVFeb2016.pdf

[26] Alaska Department of Health and Social Services, "Know the Laws About Marijuana," accessed on March 23, 2016, http://dhss.alaska.gov/dph/Director/Pages/marijuana/law.aspx.

instruction and field training exercises.[27] Certified DREs possess the expertise required to assess driver impairment from non-alcoholic drugs.

All 50 states currently participate in the Drug Evaluation and Classification program.[28] Colorado has 212 active DRE officers, more than 80 of who were certified since the legalization of marijuana.[29,30] Colorado DRE Coordinator Carol Gould explains that increases in the number of drivers determined to be impaired by DRE officers may be a consequence of the increasing number of DRE certified officers working in Colorado.[31]

Washington has also increased the presence of DRE officers on their roadways. As Table 1 shows, there were 159 DRE assessments of drivers involved in crashes in 2013, of that number 23 were determined to be under the influence of marijuana and 75 were determined to be unimpaired. Just one year later, an additional 237 DRE assessments were performed, but the number of cannabis-positive assessments increased by only one. The number of DRE assessments in which the driver was determined to be unimpaired increased by 293 percent between 2013 and 2014. Since the legalization of marijuana in Washington, the number of DRE assessments has more than doubled, but there has been no real increase in the number of marijuana-positive assessments.

Table 1: DRE Assessments in Washington State

	2013	2014	2015	Total
Under influence of Cannabis	23 (14.47%)	24 (6.06%)	27 (7.5%)	74 (8.09%)
Not Drug Impaired	75 (47.17%)	295 (74.5%)	255 (70.83%)	625 (68.31%)
Total Assessed	159	396	360	915

Source: Brown, Julie, *Drug Related Crashes,* Washington State Department of Transportation, accessed February 23, 2016.

[27] The International Drug Evaluation & Classification Program, "DRE Training & Certification," accessed February 18, 2016, http://www.decp.org/training/.
[28] The International Drug Evaluation & Classification Program, "What They Do," accessed February 18, 2016, http://www.decp.org/experts/whattheydo.htm.
[29] Colorado Department of Transportation, "Drug Recognition Experts (DRE) Program (2016),"s accessed February 18, 2016, https://www.codot.gov/safety/dre.
[30] Carol Gould (Highway Safety Manager/State DRE Coordinator), in an interview with author, February 3, 2016
[31] Carol Gould (Highway Safety Manager/State DRE Coordinator), in an interview with author, February 3, 2016

Research and Data on the Relationship between Marijuana and Traffic Safety

Published Research

In January 2016, the VT Department of Health conducted a Health Impact Assessment (HIA) of marijuana legalization's potential public health effects.[32] After a review of research related to marijuana use and risk of motor vehicle accidents the HIA states:

> Research shows increased odds of crashing, crash culpability, and fatality with increasing blood THC levels. A blood THC concentration of 5 ng/mL increased the odds of crash responsibility from 2.7 to 6.6–odds similar to that of a blood alcohol content of 0.15 percent. The exact blood level of THC associated with impairment is not known, and it is not entirely clear if blood level alone is a sufficient indicator of impairment for all users.[33]

The VT Department of Health cites evidence from three meta-analyses in addition to one longitudinal study published in 2013 (Brady and Li) for this conclusion.[34] We believe that the complexities and limitations of the extant research on this subject merit further discussion, a discussion that might lead a reader to a different conclusion from that arrived at by the VT Department of Health.

The HIA statement "a blood THC concentration of 5 ng/mL increased the odds of crash responsibility from 2.7 to 6.6 – odds similar to that of a blood alcohol content of 0.15 percent," was drawn from a 2003 study of fatally-injured drivers in Australia.[35] Drummer et al. compared the toxicology screens of drivers classified as either culpable or non-culpable in fatal accidents. Logistic regression was conducted to explore any association between likelihood of culpability and driver characteristics including age, gender, and drug use. This modelling indicated that odds of culpability in drivers testing positive for both THC and a BAC of more than .05 (units) was 2.9 times greater than the odds of drivers with BAC greater than .05 alone. This data suggests that THC enhances the impairing effects of alcohol. In cases where carboxy-THC was present but active THC was not detected, the study's data indicates no difference in the likelihood of culpability in comparison to unimpaired drivers.

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[32] Vermont Department of Health, "Health Impact Assessment: Marijuana Regulation in Vermont," January 2016, accessed on February 28, 2016, http://www.healthvermont.gov/pubs/healthassessments/documents/HIA_marijuana_regulation_in_vermont_201601.pdf.

[33] Vermont Department of Health, "Health Impact Assessment: Marijuana Regulation in Vermont," p. 5.

[34] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014," October 2015, accessed on February 18, 2015, http://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2015/10/Driver-Toxicology-Testing-and-the-Involvement-of-Marijuana-in-Fatal-Crashes_REVFeb2016.pdf.

[35] Drummer, Olaf, Jim Gerostamoulous, Helen Batziris, Mark Chu, John Caplehorn, Micael Robertson, and Philip Swann, "The involvement of drugs in drivers of motor vehicles killed in Australian road traffic crashes," *Accident Analysis and Prevention,* 943, (2003), http://www.grotenhermen.com/driving/drummer.pdf.

Brady and Li's 2013 study reviewed trends in toxicology reports for drivers involved in fatal collisions over a ten-year period in six states. The HIA states that the study's authors "reported that the number of cannabis-related fatal motor vehicle accidents in the United States tripled from 1999 to 2010."[36] Not only is the scope of Brady and Li's study insufficient to make such a claim, but the authors themselves caution that their "findings may not be generalizable to other states."[37] The HIA fails to mention that the state toxicology data used by Brady and Li does not distinguish between active THC and inactive metabolites, which may remain present in the blood for up to a week after use.[38] For this reason, the authors write that toxicology reports positive for drugs other than alcohol "should be interpreted as an indicator of drug use, not necessarily a measurement of drug impairment." Additionally, tests of deceased drivers were coded as related to as many as four drugs. Test results for a single driver which indicate a .15 BAC and any trace of THC metabolites would result in a fatality being coded as "cannabis-related."[39] Lastly, the study authors note that the period of 1999-2010 captured the implementation of medical marijuana programs in three of the six states tested, including California.[40] While the number of cannabis-positive toxicology reports increased in each state following the introduction of medical marijuana, these individual year increases were not indicative of new data trends.

A meta-analysis of epidemiological studies conducted over the past two decades explored the motor vehicle crash risk associated with THC-positive drivers. Li, Brady, DiMaggio, Lusardi, Tzong and Li assessed the research of nine studies from six different countries. These studies varied in methodology, including case-control, cross-sectional, and cohort designs.[41] Among these studies, estimated odds ratios of marijuana use and crash risk ranged from 0.85 to 7.16, where scores closer to 1 indicate the risk of motor vehicle accidents among unimpaired drivers. Seven of these studies found that "drivers who test positive for marijuana or self-report using marijuana are more than twice as likely as other

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[36] Vermont Department of Health, "Health Impact Assessment: Marijuana Regulation in Vermont," January 2016, accessed on February 28, 2016, http://www.healthvermont.gov/pubs/healthassessments/documents/HIA_marijuana_regulation_in_vermont_201601.pdf.

[37] Brady, Joanne E., and Guohua Li, "Trends in Alcohol and Other Drugs Detected in Fatally Injured Drivers in the United States, 1999–2010," *American Journal of Epidemiology*, (January 29, 2014), http://dx.doi.org/10.1093/aje/kwt327.

[38] Brady, Joanne E., and Guohua Li, "Trends in Alcohol and Other Drugs Detected in Fatally Injured Drivers in the United States, 1999–2010," *American Journal of Epidemiology*, (January 29, 2014), http://dx.doi.org/10.1093/aje/kwt327.

[39] Brady, Joanne E., and Guohua Li, "Trends in Alcohol and Other Drugs Detected in Fatally Injured Drivers in the United States, 1999–2010."

[40] Brady, Joanne E., and Guohua Li, "Trends in Alcohol and Other Drugs Detected in Fatally Injured Drivers in the United States, 1999–2010."

[41] Li, M., Brady, J.E., DiMaggio, C.J., Lusardi, A.R., Tzong, K.Y., Li, G., "Marijuana use and motor vehicle crashes." *Epidemiologic Reviews*, 34:65-72, accessed on March 14, 2016, http://epirev.oxfordjournals.org/content/34/1/65.full.pdf+html.

drivers to be involved in motor vehicle crashes."[42] Only five of the nine studies offered adjusted crash odds ratios for confounding variables, such as age, sex, and alcohol use; four of these adjusted odds ratios remained statistically significant after controlling for confounding variables. It is important to note that five of nine studies assessed exposure to marijuana based on respondents' self-reports. In countries where marijuana is an illicit drug, drivers in comparison groups may be less likely to disclose marijuana use or submit to drug testing. Studies which used self-reporting to confirm a driver's exposure to marijuana produced the greatest range of crash risk estimates, from 1.7 to 7.16.

Asbridge, Hayden, and Cartwright's meta-analysis also reviewed nine epidemiological studies of drug use and crash risk. Studies included cohort, case-control, and culpability designs. Studies of fatal collisions produced a pooled odds ratio for marijuana use and crash involvement (2.10, 1.31 to 3.36) that were statistically significant, but studies of non-fatal collisions (1.74, 0.88 to 3.46) did not yield significant results.[43] The association between marijuana use and increased risk of motor vehicle collisions was strongest in case-control studies, which compare drug use by crash-involved drivers to drug use by drivers not involved in crashes.[44] Two of these case-control studies relied upon self-report to confirm drug use among control drivers. The third study used non-drug positive, crash-involved drivers as controls for impaired, crash-involved drivers. This meta-analysis only considered studies in which marijuana exposure was confirmed by blood tests.

While meta-analyses conducted by Asbridge et al. and Li et al. provide robust research related to marijuana use and risk of motor vehicle accidents, a number of methodological constraints prevent their conclusions from being generalized beyond studies' specific contexts. Li et al.'s meta-analysis included studies which coded drivers' test results as THC-positive for the presence of carboxy-THC alone, rather than distinguish between drivers testing positive for carboxy-THC and delta-9 THC (or active THC).[45] Final pooled odds ratios for the association between marijuana exposure and crash risk incorporated five studies which did not control for driver demographics.[46]

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[42] Li, M., Brady, J.E., DiMaggio, C.J., Lusardi, A.R., Tzong, K.Y., Li, G., "Marijuana use and motor vehicle crashes." *Epidemiologic Reviews*, 34:65-72, accessed on March 14, 2016, http://epirev.oxfordjournals.org/content/34/1/65.full.pdf+html.

[43] Asbridge, M., J. A. Hayden, and J. L. Cartwright, "Acute Cannabis Consumption and Motor Vehicle Collision Risk: Systematic Review of Observational Studies and Meta-Analysis," *British Medical Journal* 344, (February 9, 2012): e536, http://dx.doi.org/10.1136/bmj.e53.

[44] Asbridge, M., J. A. Hayden, and J. L. Cartwright, "Acute Cannabis Consumption and Motor Vehicle Collision Risk: Systematic Review of Observational Studies and Meta-Analysis."

[45] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014," October 2015, accessed on February 18, 2015, http://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2015/10/Driver-Toxicology-Testing-and-the-Involvement-of-Marijuana-in-Fatal-Crashes_REVFeb2016.pdf.

[46] Li, M., Brady, J.E., DiMaggio, C.J., Lusardi, A.R., Tzong, K.Y., Li, G., "Marijuana use and motor vehicle crashes."

Asbridge et al. set cutoff levels for THC intoxication in deceased drivers between 1-2 ng/mL of active THC when categorizing crashes as cannabis-related.[47] As a result, a large number of cases considered by studies in this analysis are categorized as cannabis-related when the drivers involved would not exceed per se levels for marijuana intoxication in any state.[48]

Neither study design could control for a number of confounding variables. While regression analyses produce odds ratios adjusted for driver age, sex, and alcohol use, these methods do not consider an individual's exposure to driving or risk-taking propensity. Li et al. identify "divergent definitions and assessments of marijuana use across studies," as another factor which may confound the association between marijuana exposure and risk of motor vehicle accidents. Furthermore, both meta-analyses used studies which did not provide sufficient data related to drugs other than marijuana or alcohol. For this reason Asbridge et al. calculated odds ratios for crash risk for drivers testing positive for cannabis without any other drugs or alcohol present. Li et al. write at greater length regarding the issues of assessing traffic accident risks associated with polydrug use:

> "Polydrug use represents another challenge to determining the role of marijuana in motor vehicle crashes. Polydrug use by drivers is common, with up to a quarter of drivers injured in crashes testing positive for 2 or more drugs (including alcohol) (42, 73, 74). Although it is necessary to understand the effect of individual drugs on driving performance, the high prevalence of polydrug use by drivers makes it difficult to do so. On the other hand, assessing interaction effects on driving safety of different drug combinations based on epidemiologic data would require very large study samples, comprehensive drug testing data, and tremendous financial and other resources (42–44, 75, 76)."[49]

In its analysis, the HIA did not consider the National Highway Traffic Safety Administration's (NHTSA) 2015 study of drug use and crash risk.[50] Although it is only a single piece of research, the study, described as the first large-scale study of crash risk in the United States to assess drugs other than alcohol, contradicts the estimates of cannabis-related crash risk provided by the two meta-analyses.[51] Collecting data from more than 9,000 drivers over twenty months in Virginia Beach, Virginia, the NHTSA study paired each crash-involved drivers with two controls randomly selected from a population of drivers operating vehicles under similar conditions. Crash-involved drivers and control drivers

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[47] Li, M., Brady, J.E., DiMaggio, C.J., Lusardi, A.R., Tzong, K.Y., Li, G., "Marijuana use and motor vehicle crashes." *Epidemiologic Reviews*, 34:65-72, accessed on March 14, 2016, http://epirev.oxfordjournals.org/content/34/1/65.full.pdf+html.

[48] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014."

[49] Li, M., Brady, J.E., DiMaggio, C.J., Lusardi, A.R., Tzong, K.Y., Li, G., "Marijuana use and motor vehicle crashes."

[50] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014."

[51] Vermont General Assembly, Senate Health and Welfare Committee, "Malik Burnett: Written Testimony," accessed on February 18, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/Senate%20Health%20and%20Welfare/Marijuana/W~Malik%20Burnett~Written%20Testimony~1-20-2016.pdf.

alike were tested for intoxication via oral fluid and blood. Data revealed no increase in population-based crash risk associated with THC use.[52] Analyses controlling for driver age, gender, ethnicity, and alcohol concentration level indicate individuals testing positive for active-THC were no more likely to crash than sober drivers.[53] The study's authors estimate an adjusted odds-ratio between active THC and crash risk to be 1.00, where scores closer to 1 indicate the same risk of crash as for unimpaired drivers. The crash risk associated with a .08 blood alcohol concentration, adjusted for age and gender, was estimated at 3.98; drivers with this blood alcohol concentration may have been nearly four times more likely to be involved with a car accident than unimpaired drivers.[54] While this study does overcome some methodological constraints observed in earlier epidemiological studies of drug use and crash risk (through careful matching of case and control samples, a large number of subjects, and consistent drug testing methods), the NHTSA's study includes a crash distribution biased toward less severe events.[55] Like earlier studies, the NHTSA's study design could not account for individual factors affecting impairment by THC, including a driver's past experience with THC or the potency of marijuana ingested.

While these studies offer different conclusions on the effect of marijuana on actual driving, two different laboratory studies cited in the WTSC report conclude marijuana has a detrimental effect on cognitive human capacities related to driving.[56] These studies used driving simulators to determine that human capacities were diminished by the use of marijuana, such as reaction time, concentrated attention, and speed variability. These studies also determined that these capacities became severely limited with the added presence of alcohol**.** Regular marijuana users who may exhibit lower performance deficits while driving may still be seriously impaired after consuming alcohol. Though regular marijuana users may compensate for their performance decrements by taking fewer risks while driving, alcohol consumption may inhibit such behaviors. However, the WTSC report provides some words of caution: "Simply 'converting' the findings from laboratory and simulator studies to on-road driving performance effects has resulted in unwarranted conclusions." Controlled lab experiments may not accurately reproduce real driving conditions. Furthermore, alcohol and marijuana differ in "chemical makeup, body metabolism, and psychomotor impairment and therefore should not be compared."

Data on Crashes and Crash Risks

The HIA includes a brief overview of marijuana legalization's effects on crash risk in Washington and Colorado, but does not provide important context for fatality and accident

[52] National Highway Traffic Safety Administration, "Drug and Alcohol Crash Risk Study, Executive Summary," accessed on February 18, 2016, http://www.nhtsa.gov/staticfiles/nti/pdf/11388a-CrashRiskStudy-ExecSummary.pdf.
[53] National Highway Traffic Safety Administration, "Drug and Alcohol Crash Risk, Research Note."
[54] National Highway Traffic Safety Administration, "Drug and Alcohol Crash Risk, Research Note."
[55] National Highway Traffic Safety Administration, "Drug and Alcohol Crash Risk Study, Executive Summary," accessed on February 18, 2016, http://www.nhtsa.gov/staticfiles/nti/pdf/11388a-CrashRiskStudy-ExecSummary.pdf.
[56] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014."

trends. Summary reports from both states use data collected for the NHTSA's Fatality Analysis Reporting System (FARS).[57] A FARS summary of fatality data for all states is published annually. Currently, FARS data is available only through 2014.

The report prepared by the WTSC summarizing trends in driver toxicology testing from 2010 to 2014 highlights some limitations associated with the FARS data. FARS data is not coded to distinguish between carboxy-THC and active THC. Additionally, FARS reports only record whether or not an intoxicant was present in a driver's system, rather than specify an observed amount.[58]

The FARS analysts involved with the WTSC report gleaned cannabinoid drug results for drivers involved in fatal crashes from state toxicology reports to analyze data from marijuana-related accidents.[59] Test results for drivers who are suspected of DUI during the course of traffic stops or crash investigations are sent to the Washington State Patrol Toxicology Lab for analysis. Currently the lab only uses drug result data in the case of roadway fatalities.

The WTSC report considers fatal crash data only, not a population-based dataset. The report notes that intoxicated drivers in fatal crashes are typically higher risk drivers who engage in behaviors not typical of the larger driving population. While the NHTSA study controls for demographic variables (age, gender) associated with high risk behaviors, the WTSC report does not. Washington State crash data does not specify whether or not drivers involved in fatal accidents were at fault. For these reasons, trends observed among toxicology reports of deceased drivers cannot be generalized to whole populations of drivers in other states.

Additionally, the HIA does not mention the change to the Washington State Patrol Toxicology Lab's testing procedures and policies. As of the WTSC report's publication, the Toxicology Lab did not distinguish between carboxy-THC and active THC when categorizing test results.[60] For this reason, the WTSC report states that in the case of drivers involved with fatal crashes and testing positive for marijuana, "the actual impairment or contributing crash effect by marijuana, if any, is unknown."[61] In 2013 the Lab lowered its testing cutoff for active THC from 2 ng/mL to 1 ng/mL; in that same year the Lab began testing drivers with blood alcohol concentrations .08 percent for drug intoxication, whereas previously these drivers would not have been tested beyond

[57] National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS) (2016), accessed February 18, 2016, http://www.nhtsa.gov/FARS.
[58] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014."
[59] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014."
[60] Staci Hoff, Research Director for Washington Traffic Safety Commission, in e-mail message to authors, January 18, 2016
[61] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014

confirmation of alcohol.[62] Due to the limitations of the FARS system and current testing practices used to assess marijuana intoxication, the WTSC specifies that its observations are not sufficient evidence to determine an association between THC-levels and crash risk.

The HIA cites data from the Rocky Mountain High Intensity Drug Trafficking Area's (RHMIDTA) September 2015 report when introducing Colorado's post-legalization traffic trends. As in Washington, more context is necessary to make sense of cannabis-related driving statistics from Colorado. The RMHIDTA's report definition of marijuana citations includes instances where marijuana was present "based on official opinion only (no toxicological confirmation)."[63] The report's definition of marijuana DUID is expansive enough to encompass those instances where officer observations were "not necessarily indicative of legal intoxication."[64] Additionally, cutoff standards for active THC in drug tests were lowered from 2 ng/mL to 1 ng/mL in 2014. The RMHIDTA report measures active THC by a 1 ng/mL cutoff standard, which is 80 percent lower than the state's legal standard for cannabis intoxication (5 ng/mL).

Data on Traffic Incidents

The authors of the RAND Corporation report, "Considering Marijuana Legalization," suggest that the influence of legalization upon traffic safety is best assessed via changes in a state's traffic accident or fatality rates.[65] Figure 1 illustrates the total number of traffic fatalities in Washington, Colorado, and Vermont from 2005 through 2014. During this period fatalities decreased for all states by at least 19 percent, even without accounting for population growth or total miles traveled. Total traffic fatalities for the entire United States declined by 25 percent within the same period.

The year 2013 marked the first full calendar year in which recreational marijuana was legal in Colorado and Washington. Between 2012 and 2013 the number of traffic fatalities increased by 1.6 percent in Colorado while decreasing by .04 percent in Washington. Both states opened commercial marijuana markets in 2014, though retail sales in Washington lagged six months behind Colorado. From 2013 to 2014, traffic fatalities increased by 1.2 percent in Colorado and 5.9 percent in Washington. In Vermont total traffic fatalities have been relatively stable over the past decade**.** Decriminalization of marijuana in 2013 has not affected this trend. In 2012 there were 77 traffic fatalities, just 69 in 2013 and 44 in 2014 (a ten-year low).

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[62] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014."

[63] Rocky Mountain High Intensity Drug Trafficking Area, "The Legalization of Marijuana in Colorado, The Impact," September 2015, accessed on February 18, 2015, http://www.rmhidta.org/html/2015%20FINAL%20LEGALIZATION%20OF%20MARIJUANA%20IN%20COLORADO%20THE%20IMPACT.pdf.

[64] Rocky Mountain High Intensity Drug Trafficking Area, "The Legalization of Marijuana in Colorado, The Impact."

[65] Caulkins, Jonathan P., Beau Kilmer, Mark A. R. Kleiman, Robert J. MacCoun, Gregory Midgette, Pat Oglesby, Rosalie Liccardo Pacula and Peter H. Reuter. "Considering Marijuana Legalization: Insights for Vermont and Other Jurisdictions," Santa Monica, CA: RAND Corporation, 2015, http://www.rand.org/pubs/research_reports/RR864.html.

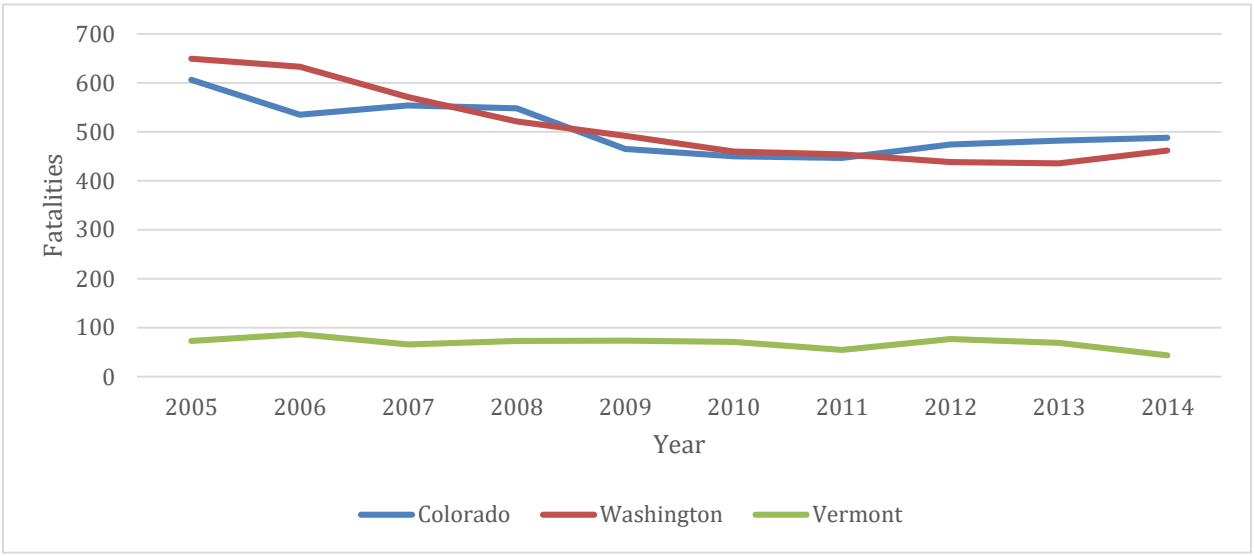

Figure 1: Total Traffic Fatalities

Source: Source: Fatality Analysis Reporting System Encyclopedia, National Highway Traffic Safety Administration, accessed Febuary 23, 2016, http://www.fars.nhtsa.dot.gov/Main/index.aspx.

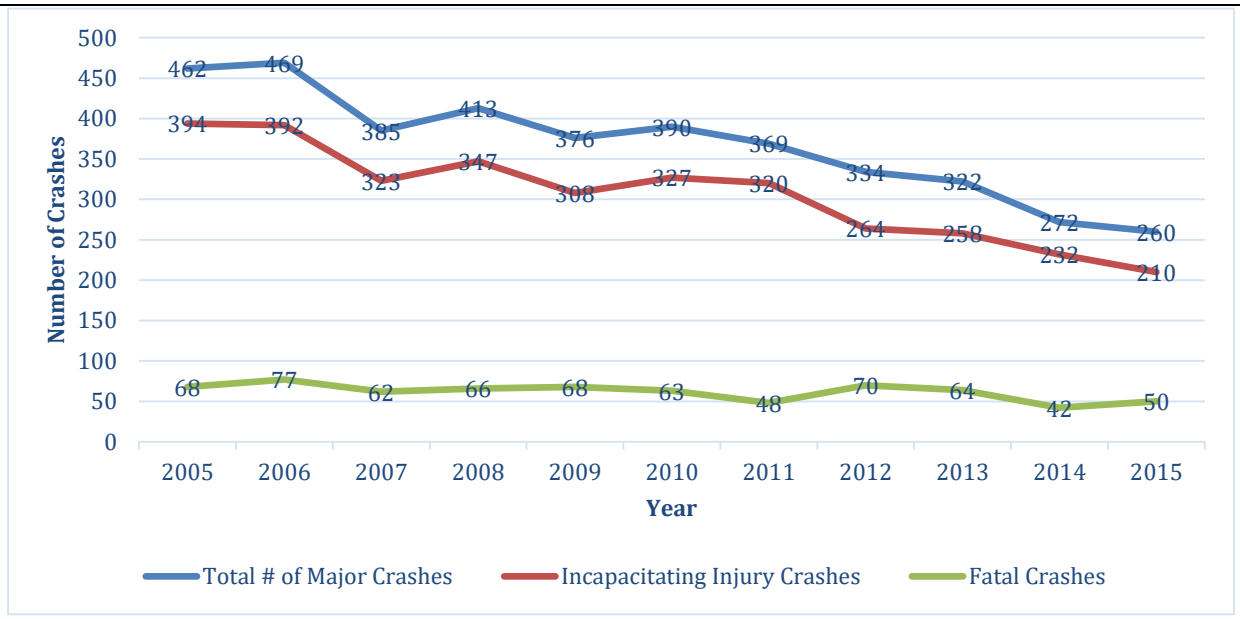

Figure 2: Vermont Major Crashes

Source: Vermont General Assembly, House Committee on Judiciary, "H.560: Vermont Major Crashes," accessed on February 23, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/House%20Judiciary/Bills/H.560/W~Kevin%20Marshia~Vermont%20Major%20Crashes~1-6-2016.pdf.

Figure 2 shows data collected by VTrans including the number of total number of major crashes, incapacitating injury crashes, and fatal crashes in Vermont since 2005.[66] These data show that the number of major crashes and incapacitating injury crashes have declined each year since 2010. This includes 2015, for which FARS data are not yet available.[67]

Figure 3 illustrates the number of marijuana-positive drivers in fatal collisions in Colorado from 2003-2014 and Washington from 2008-2014. This data was collected by each state's Department of Transportation as part of the FARS data collection.

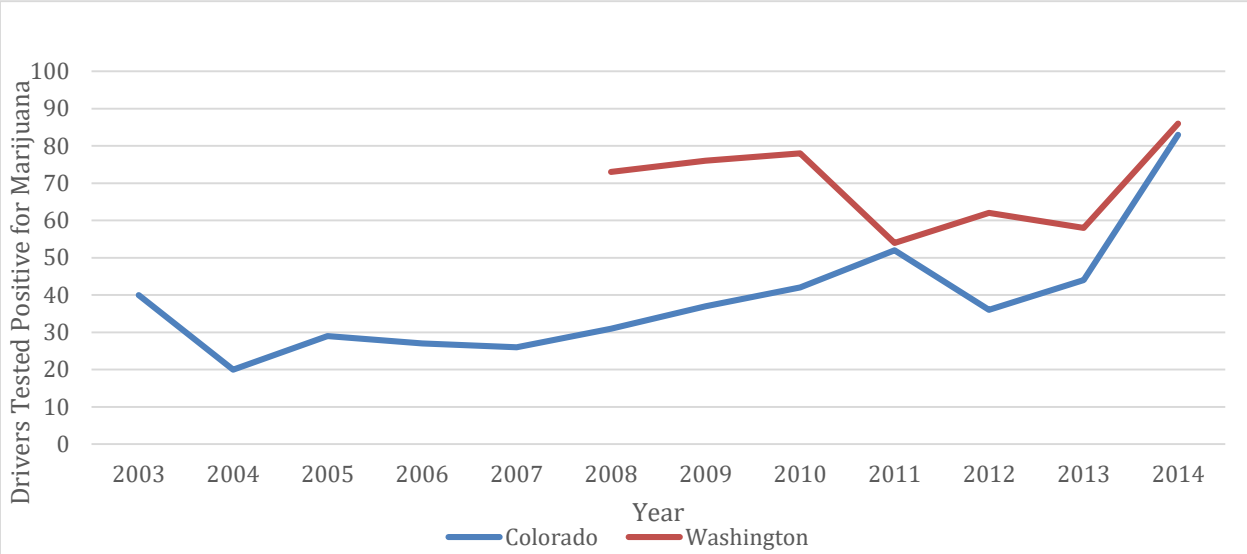

Figure 3: Marijuana Positive Drivers in Fatal Collisions

Sources: *Drugged Drivers in Fatal Collisions*, 2015, prepared by the Colorado Department of Transportation, accessed February 23, 2016, https://www.codot.gov/library/traffic/safety-crash-data/fatal-crash-data-city-county. Staci Hoff, Research Director for Washington Traffic Safety Commission, in an e-mail to the authors, January 18, 2016.

While Figure 3 shows a rise in marijuana-positive drivers in fatal collisions, the data are imperfect for a number of reasons. First, this data do not distinguish between the active and inactive THC so the actual impairment of these drivers is unknown.[68] That increase would be expected to show up on this chart as well. It does not mean more drivers were

[66] Vermont General Assembly, House Committee on Judiciary, "H.560: Vermont Major Crashes," accessed on February 23, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/House%20Judiciary/Bills/H.560/W~Kevin%20Marshia~Vermont%20Major%20Crashes~1-6-2016.pdf.
[67] Vermont General Assembly, House Committee on Judiciary, "H.560: Vermont Major Crashes."
[68] Staci Hoff, Research Director for Washington Traffic Safety Commission, in e-mail message to authors, January 18, 2016

under the influence of marijuana in fatal collisions, just that more drivers in fatal collisions had THC, perhaps non-active THC, in their system.

Another issue with the data provided in Figure 3 is that Washington and Colorado both changed their testing policies after legalization. In 2013 Washington began testing on all traffic crash blood sample submissions—previously they had only tested when blood alcohol concentrations were below .10.[69] Consequently, more drivers involved in fatal crashes in Washington have been tested for marijuana intoxication since 2013, whereas in previous years these drivers would have only been categorized as under the influence of alcohol. Additionally, Washington and Colorado (in 2013 and 2014, respectively) lowered testing thresholds for marijuana intoxication from 2 ng/ml to 1ng/ml. Since these changes have taken effect, a greater number of drivers involved in fatal collisions have been categorized as marijuana-positive.

Conclusion

This report has examined the potential traffic safety impacts of legalizing marijuana. Four states have legalized recreational marijuana. Some states have opted to amend existing DUI laws to incorporate *per se* limits for marijuana intoxication. Colorado and Washington test for THC in a drivers blood, these tests can detect active THC in the blood long after the effects of marijuana have passed.[70] Several states are starting to use oral fluid tests which have the advantage of easy on-site testing. However, oral fluid tests cannot assess specific levels of intoxication, just the presence of THC in an individual's system. States which have legalized marijuana make extensive use of DRE-certified officers when assessing drivers for drug impairment.

Simulator studies and laboratory experiments have found performance decrements in driving-related tasks due to drug impairment.[71] Marijuana use affects human capacities including reaction time, concentrated attention, and speed variability. While this research is telling about marijuana's affects in a laboratory environment, these results cannot be generalized to make conclusions about marijuana's affect on actual on-road driving performance.

A review of relevant literature suggests an association between marijuana use and crash risk. Two recent meta-analyses of epidemiological studies exploring drug use and motor vehicle accidents independently concluded that THC-positive drivers may be nearly twice as likely to be involved in traffic accident as unimpaired drivers. A recent NHTSA study

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[69] Washington Traffic Safety Commission, "Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014," October 2015, accessed on February 18, 2015, http://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2015/10/Driver-Toxicology-Testing-and-the-Involvement-of-Marijuana-in-Fatal-Crashes_REVFeb2016.pdf.

[70] Vermont General Assembly, Senate Committee on Health and Welfare, "Malik Burnett: Written Testimony," accessed on February 18, 2016, http://legislature.vermont.gov/assets/Documents/2016/WorkGroups/Senate%20Health%20and%20Welfare/Marijuana/W~Malik%20Burnett~Written%20Testimony~1-20-2016.pdf

[71] National Highway Traffic Safety Administration, "Drug and Alcohol Crash Risk, Research Note."

found that drivers testing positive for active THC were no more likely to be involved in a traffic accident than sober drivers, after controlling for driver demographics and alcohol use.[7273]

Since legalization of marijuana, Colorado and Washington have experienced increases in their total number of traffic fatalities: in 2014 Colorado's total traffic fatalities rose by 1.2 percent and Washington's rose by 5.9 percent. These states have also witnessed a significant increase in the number of deceased drivers testing positive for past marijuana use, but these increases may be due in part to recent changes in testing practices. With all these considerations in mind, it seems that it is too early to make any conclusions about how marijuana has affected traffic safety in any of the states that have legalized.

This report was completed on March 24, 2016 by Max Knutsen and Scott Pavek under the supervision of Professors Jack Gierzynski, Robert Bartlett and Professor Eileen Burgin.

Contact: Professor Anthony Gierzynski, 517 Old Mill, The University of Vermont, Burlington, VT 05405, phone 802-656-7973, email agierzyn@uvm.edu.

[72] Note: Odds-ratios used to estimate risk of crash involvement were adjusted to control for a number of demographic and behavioral variables, including age, gender, and alcohol use.
[73] National Highway Traffic Safety Administration, "Drug and Alcohol Crash Risk, Research Note."