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Cannabis Use among Drivers Suspected of Driving Under the Influence or Involved in Collisions:

Analysis of Washington State Patrol Data

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Title

Cannabis Use among Drivers Suspected of Driving Under the Influence or Involved in Collisions: Analyses of Washington State Patrol Data. *(May 2016)*

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About the Sponsor

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Founded in 1947, the AAA Foundation in Washington, D.C. is a not-for-profit, publicly supported charitable research and education organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, from individual members, from AAA-affiliated insurance companies, as well as from other organizations or sources.

Executive Summary

Introduction

In 1999, Washington State voters approved the legalization of medical marijuana. In November 2012, Washington voters passed Initiative-502 (I-502), legalizing retail cannabis sales and recreational cannabis use for adults 21 years and older. As with alcohol, the law provides two options for prosecuting suspected impaired drivers: 1) demonstrating impairment through detailed observation notes, field test results, witness observations, or Drug Recognition Expert assessments; and 2) determining the suspect's blood level for the drug is above the legal "*per se*" limit. I-502 established a *per se* level of 5ng/mL of active delta-9-tetrahydrocannabinol (hereafter THC) in blood for cannabis-impaired driving. THC is a psychoactive compound in cannabis.

The objectives of this study were to examine drivers involved in collisions and/or arrested for suspected driving under the influence (DUI), who were investigated by the Washington State Patrol and for which blood evidence was collected in order to: describe the trends in THC involvement over time and in relation to the passage of I-502; to describe the prevalence of THC alone and in combination with alcohol and other potentially intoxicating drugs; and to describe the estimated time to blood draw under real world conditions, and examine the relationship between estimated time to blood draw and the level of THC detected. Additionally, to provide necessary context, law enforcement and toxicology testing procedures as well as arrests, state patrol staffing levels, and training over the study period were documented.

Methods

Semi-structured interviews were conducted with law enforcement, prosecutors, and toxicology laboratory staff. Documents were reviewed to determine DUI arrests, law enforcement staffing and training over time. Data from the Washington State Patrol's toxicology laboratory, dispatch, and officer activity log were linked. Longitudinal analyses were conducted to test trends over time from 2005 to 2014 for the presence and level of THC (excluding alcohol-involved cases due to changes in laboratory procedures in 2013). We also explored whether there was a change in the presence of THC following the passage of I-502. Driver characteristics including drugs detected were explored for collisions and/or for those with suspected DUIs that did not involve a collision. An estimated time to blood draw (ETBD) variable was created from data in the computer automated dispatch system. The relationship between the estimated time to blood draw and measured THC level was tested.

Main Results

<u>Law enforcement staffing and training, arrests, policies and procedures</u>

- From 2009-2014, the overall number of Washington State Patrol (WSP) troopers assigned to traffic enforcement was relatively unchanged. However, there was an increase in the number of state patrol officers with specialized training in Advanced Roadside Impaired Driving Enforcement (109 in 2009, compared with 669 in 2013) with the potential impact of increased sensitivity and ability to identify THC-impaired driving. In April of 2013, the Missouri v. McNeely court opinion was issued

which essentially required a warrant for DUI-related blood tests. Washington State Patrol DUI-related arrests declined from 2012 onwards.

Trends in THC-involved driving

- Between 2005 and 2014, the proportion of Washington State DUI and collision cases tested by toxicology, excluding those positive for alcohol, that involved THC increased significantly, from 20 percent to 30 percent. Among these cases, the prevalence of THC continued to grow after passage of I-502 in 2012, but at a significantly slower pace.
- The median blood level of THC increased significantly from 4.0ng/mL in 2005 to 5.6ng/mL in 2014 (p for trend = 0.015).

Prevalence of THC in collisions and suspected DUIs

- Among drivers for whom blood evidence was submitted following a collision, 11 percent were positive for THC in conjunction with another potentially impairing substance (alcohol or other drugs). An additional 4 percent were positive for THC only. The majority (53%) of collision involved drivers were under the influence of alcohol at a level of 0.08 g/dL or higher, and 7 percent met or exceeded the *per se* level of THC, 5ng/mL.
- Among drivers suspected of DUI in the absence of a collision, 11 percent were positive for THC in conjunction with another potentially impairing substance. An additional 26 percent tested positive for THC only. Non-collision-involved drivers arrested for DUI were most commonly under the influence of alcohol at 0.08 g/dL or above (30%). Among these drivers, 20 percent had a THC level of 5ng/mL or above.

Estimated time to blood draw

- The median time to blood draw for all cases was 165 minutes.
- The median estimated time to blood draw for THC-positive drivers (among collisions and non-collisions) was 139 minutes. Estimated time to blood draw was significantly longer for those positive for the inactive metabolite carboxy-THC, but not THC, at the time of testing (175 minutes).
- The measured THC blood level for the population studied declined 5ng/mL on average during the first 120 minutes from contact with police.
- The proportion of those with an estimated time to blood draw of less than 2 hours who had a THC blood level greater than or equal to 5ng/mL was 26 percent compared to 10 percent for those with an estimated time to blood draw of 2 hours or more.

Implications

Evaluating the impacts of cannabis legalization on the prevalence of THC detection in blood evidence from collisions and suspected DUI cases is complicated by historical factors related to other laws, policies liberalizing cannabis access and use as well as likely improved capacity to detect drug-impaired driving. It is likely that prolonged delays in blood testing routinely resulted in those who were above the 5ng/mL THC *per se* limit at the time of a collision or driving violation being below this level by the time blood was drawn.

In the context of historical changes and data limitations, we documented an increase in the proportion of DUI cases involving THC and an increase in the level of THC in cases from 2005-2014 among cases tested by toxicology, excluding those positive for alcohol, however there was no additional increase related to the passage of I-502 in 2012. Among drivers in collisions, the majority (53%) were alcohol-impaired at a level of 0.08 g/dL or higher and 7 percent met or exceeded the *per se* level of THC, 5ng/mL. Drivers arrested for suspected DUI in the absence of a collision were most commonly under the influence of alcohol, with 30 percent at 0.08 g/dL or above, and 20 percent had a THC level of 5ng/mL or above. Overall the average estimated time to blood draw was 165 minutes. These findings indicate that THC–involved driving is relatively common, appears to be increasing and is likely underestimated given the generally protracted time until a blood specimen is obtained. Evaluating the impact of protracted time until blood testing is complicated by the lack of available standardized law enforcement data on the time of testing. These findings highlight the challenges in enforcing drugged driving laws, particularly with a *per se* component, in the absence of point-of-contact testing modalities and in the presence of logistical delays in obtaining blood specimens.

Introduction

Cannabis use is widespread in the United States with an estimated 9.5 percent of adults reporting past year use in 2012-2013, more than double the prevalence in 2001-2002[1]. The legal landscape is changing rapidly: many states have adopted medical cannabis laws over the past 15 years and others have moved towards recreational legalization or decriminalization starting in 2012. Cannabis is a Schedule I drug under federal law, indicating that its use is illegal for any purpose. However, the U.S. federal government has been reticent to interfere with state laws legalizing cannabis use for adults.

In Washington state, voters approved medical marijuana in 1999 and in Seattle in 2003 and Tacoma in 2011 voters passed initiatives declaring marijuana possession offenses the lowest law enforcement priorities[2]. In November 2012, Washington State voters passed ballot Initiative-502 (I-502), with the goal of permitting recreational cannabis use [3]. I-502 made it legal to license and regulate cannabis production, distribution, retail sales, and possession for persons age 21 and over; removed state-law criminal and civil penalties for specified activities; introduced taxes on cannabis sales; and earmarked cannabis-related revenues.

The objectives of this study were to: 1) document DUI related procedures and law enforcement staffing levels and training over time 2) describe the temporal trends in cannabis use in suspected impaired driving and collision cases between 2005 and 2014 in Washington State and examine whether the passage of I-502 was associated with changes in cannabis-involved driving; 3) characterize the patterns of potentially impairing substances among drivers suspected of DUI and/or involved in collisions; and 4) characterize the relationship between measured delta-9-tetrahydrocannabinol (hereafter THC) blood levels and the elapsed time between DUI stop/collision and blood draw using a novel law enforcement dataset.

Estimates of marijuana use and risk perception in Washington State

To provide some context for trends in cannabis-involvement in collisions and suspected DUIs over time, data on cannabis use, risk perceptions, and legal retail sales are provided.

Cannabis use rates and risk perception among Washington youth have been tracked for more than a decade through the Healthy Youth Survey administered in schools. Among Washington 12th grade students, self-reported cannabis use increased steadily from 2004 through 2014, so that by 2014 more than one in four adolescents (27%) reported marijuana use in the past 30 days[4]. The proportion of high school students who believed that there was "low or no risk" from using marijuana regularly rose from 20 percent to 45 percent over the same period. For the first time, the 2014 survey included questions about cannabis and driving behaviors. For 12th graders, 17 percent reported driving after using cannabis in the prior 30 days and 26 percent reported riding with a driver who had used cannabis.

The Washington State Young Adult Health Survey was conducted in 2014 in order to learn about the attitudes towards and use of drugs and alcohol among Washington residents aged 18 to 25 years[5]. Among these young adults, 43 percent reported using cannabis for recreational purposes in the past year, and one-quarter (24%) reported that they had used marijuana within the past month. Among past month cannabis users, half (49%) reported

they had driven within three hours of using cannabis. The survey did not limit that response to individuals who drive, so the proportion of drivers who had consumed cannabis within three hours is likely somewhat higher than reported.

The WA State Behavioral Risk Factor Surveillance System survey began tracking adult cannabis use rates in 2011 for adults ages 18 and older, the prevalence of past 30 day use of cannabis was 9 percent in 2013, up slightly compared to the prior two years[7]. From the 2013-2014 National Survey on Drug Use and Health Washington State can be compared to national averages for past month use of marijuana: ages 18+ 13 percent (compared to 8 percent nationwide), ages 18-25 24 percent (compared to 19 percent nationwide), ages 26+ 11 percent (compared to 6 percent nationally) [6].

Retail marijuana sales

Stores licensed to sell recreational cannabis began opening, slowly, in the summer of 2014. Washington legislation passed in 2015 will further modify the medical cannabis market by increasing regulatory oversight of sales beginning in 2016[3]. Legal retail sales at the producer, processor and retailer level increased dramatically from July 2014 through June 2015 in Washington State. In June 2015 cannabis sales totaled $45.8 million[7].

Cannabis and driving: Legislation and evidence base

To address cannabis-impaired driving, Washington State's Initiative-502 set a *per se* level of 5 ng/mL of THC in whole blood for driving under the influence (DUI), in addition to the "under the influence of or affected by" option that was in place prior to I-502. THC is the main psychoactive and potentially impairing component of cannabis. THC is generally measureable in blood for several hours following consumption and metabolization varies widely by route of administration, potency, and user characteristics[8 9–14]. Some consensus exists on 2-4 hours of effects after smoking, decreasing quickly after maximum impairment at 20-40 minutes, but higher THC-content smoke has longer effects[10,11,15–17] and mild effects have been documented at 6 hours or more post dosage[13,17] . Slower absorption of oral doses (e.g. edibles), particularly in presence of other food, creates a delayed and longer-lasting peak blood level[13,18] that is typically much lower than results from smoking. Metabolism and neurological effects of THC also depend upon the levels of other cannabinoids in the consumed substance[15]. The presence of THC in blood at levels above 1 ng/mL is generally an indication of recent cannabis consumption for occasional users. Carboxy-THC is a readily detected non-psychoactive metabolite of cannabis. The metabolite carboxy-THC may remain measureable for several days following occasional use, and longer with more frequent use[24].

Laboratory studies of cannabis and driving simulator studies have repeatedly demonstrated that THC use is associated with impairment in driving related behaviors. Acute cannabis use has been shown to moderately diminish virtually every driving-related capacity, generally in a non-linear dose-response fashion: psychomotor functions, cognition, attention, vigilance, tracking, reaction time & coordination[10,11,15,16,19,20]. Cannabis affects automated/routine driving more than that requiring conscious effort [14,16]. Effects depend on dose, potency, absorption, time since peak blood level, individual tolerance and skill/task[16,18,19].

However, real world studies examining the association between cannabis use (THC presence and level) and collision risk have been inconsistent. A recent case-control study compared oral fluid and blood test results of more than 3,000 drivers involved in a collision with over 6,000 control drivers recruited from the same location, traveling in the same direction, and at the same time of day. All drivers voluntarily participated in the study. In multivariable analyses controlling for the presence of alcohol or other potentially intoxicating drugs, investigators found no significant association between collision risk and testing positive for THC, after adjusting for demographic variables[21].

Epidemiologic studies exploring crash risk factors have relied on the Fatal Accident Reporting System (FARS). For instance, a study examined the presence of THC and its metabolites reported in the FARS system for Colorado to states without widespread medical marijuana to test for the impacts on fatal crashes and found increases "in the proportion of drivers in a fatal motor vehicle crash who were marijuana-positive" in Colorado but not in non-medical marijuana states[22]. However, the FARS system contains information on drug presence, rather than impairment, which may reflect active or inactive drug metabolites. In addition, due to variations in testing between and within states, the National Highway Traffic Safety Administration has cautioned against such comparisons[23]. An additional challenge with fatal cases is that metabolization essentially stops at the time of death, so blood levels among those who have died will on average be much higher than those who live and whose time to a blood test may be several hours later[25,26].

Intent of analyses

To address important policy and procedural questions regarding THC-involved driving in the context of legalization, we conducted a series of analyses. The impact of legalizing cannabis on impaired driving is an important policy question and so we analyzed trends over time and tested whether trends changed following the passage of I-502. In order to understand more about the possible impacts of cannabis, we examined the presence and level of THC among drivers involved in collisions or arrested for suspected DUI for which blood was tested. Because Washington State has a *per se* blood level of 5ng/mL for THC, and THC metabolizes rapidly, the time to blood draw is potentially important for understanding and interpreting laboratory results to detect THC and its inactive metabolite carboxy-THC, hence we examined the estimated time to blood draw and the relationship to THC levels measured in blood[27].

Methods

Analytic data sources

1. Toxicology (TOX) data from the WSP Forensic Laboratory Services Bureau report levels of different drugs or their metabolites: carboxy-THC, THC, ethanol, and other potentially intoxicating drugs. The laboratory tests toxicological evidence for all Washington state and local law enforcement jurisdictions. Cases involving suspected DUI or serious motor vehicle collisions are included for 2005-2014.

2. Computer Automated Dispatch (CAD) data from the WSP provide a time stamped progression of a case from initial dispatcher involvement onwards. Of specific interest for these analyses were: a collision indicator variable, the beginning time of the case, and an estimate of when a blood draw was obtained.

3. Time and Activity Reports (TARs) are completed by WSP officers bi-weekly and are entered into an administrative database. TARS record all traffic stops and identify the primary reasons for the traffic stop. TARS reports include the hours worked and the activities of the officer. For these analyses we used up to three violation codes for each infraction; (e.g. speeding, lane change and non-functioning turn signal). For each case, officers also document the road type (interstate, state, county), contact type (e.g. officer-initiated, emphasis patrol) and observed ethnicity which are other variables important for understanding the characteristics of these cases.

Methodological approach and analyses

Documentation of law enforcement staffing and training, arrests, policies and procedures (Objective 1)

Semi-structured interviews were conducted via phone to determine policies and practices ranging from patrol officers' training and staffing levels to the final reporting of toxicology results. Interviews were conducted with:

- The Washington State Patrol (WSP) Impaired Driving Section Lead
- A WA State Traffic Safety Prosecutor
- 10 WSP Officers - representatives from the 8 WSP districts (1 district is geographically divided and required speaking with 3 representatives – one from each area of the district). Included 4 captains, 2 lieutenants and 4 sergeants.
- 7 local law enforcement officers including 3 county deputies and 4 municipal officers from various parts of the state and different size departments.
- 5 county prosecutors –from a variety of areas (geographic location and size/population)

The dates of major changes in practice and policy were documented. Annual totals of DUI related court filings, arrests and WSP staffing and training were obtained. Summary

documents, particularly the typical flow of a DUI case and timeline and impact of major policy changes, were reviewed by the study advisory committee for accuracy.

Longitudinal analyses of THC-positive cases (Objective 2)

We created an analytic data set from 2005 through 2014, in order to examine changes in time-dependent DUI and collision cases involving THC from the toxicology laboratory. To examine trends over time, prevalence differences were calculated using binomial regression models with the identity link for cases involving THC with or without other substances and separately for cases involving only THC. Time (the main independent variable of interest in these analyses) was treated once as a continuous measure (to determine the "average annual change" over the study period) and separately as a categorical measure using dummy indicator variables (to determine the difference between each year and the reference year and allow for any departure from linear trend). In additional analyses, binomial regression models were constructed to examine the impact of the passage of I-502 in November 2012 on longitudinal trends of THC-positivity. In these analyses, the presence of I-502 was coded as a dichotomous variable (0: prior to the passage; 1: following the passage). A continuous variable for time, as well as an interaction term between presence of I-502 (dichotomous) and time (continuous) were added to the models. The coefficient for that interaction term provided inference on the difference in the slope (trajectory) of THC-positivity before vs. after the passage of I-502 (i.e., difference in differences). To test changes in the median level of THC over time, a linear regression with median THC as the outcome (continuous variable) and time (year) as the independent variable was utilized.

THC and other substances detected in drivers suspected of DUI or involved in collisions (Objective 3)

The presence and level of THC and other potentially intoxicating substances for various case types were examined. Data from April 2013 through December 2014 were utilized for these analyses as the WSP's computer automated dispatch (CAD) system was completely replaced in April 2013 and only data during this time frame were comparable.

Analysis of estimated time to blood draw and THC levels (Objective 4)

Graphs displaying the level of THC versus carboxy-THC by the estimated time to blood draw (ETBD) obtained from computer automated dispatch (CAD) data were created to show the distribution of cases by estimated blood times. We conducted Wilcoxon rank-sum test tests of differences in median blood draw times for THC versus carboxy-THC. A scatter plot with locally weighted regression lines was created to examine the relationship between ETBD and THC level. Linear regression analyses were conducted to test the relationship between ETBD and THC level and whether the relationship differed for those with an ETBD of less than two hours compared to two to four hours using a piecewise regression analysis (with a priori 2-hour cut point).

Table 1 provides an on overview of each study objective, the scope of the data, the case types included, and the specific data sources utilized.

Table 1- Objectives, study populations and datasets

Objective	Scope/Case types	Data sources
Objective 1 Documentation of law enforcement staffing and training, arrests, policies and procedures.	Policies and procedures focused on WSP cases. 2005-2014	Interviews with state and county prosecutors Interviews with WSP captains or their representatives, and other local law enforcement personnel across WA State WSP DUI arrests, ARIDE training and other internal statistics through public information requests
Objective 2 Longitudinal analyses of THC-positive cases	All law enforcement cases with evidence sent to state toxicology lab for DUI testing. 2005-2014	WSP Toxicology
Objective 3 THC and other substances detected in drivers suspected of DUI or involved in collisions	Washington State Patrol traffic cases where blood specimens were sent to the state toxicology lab for testing Cases with records that could be matched across datasets April 2013-December 2014	WSP Toxicology WSP Computer Automated Dispatch WSP Time and Activity Reports
Objective 4 Analysis of estimated time to blood draw and THC levels	Washington State Patrol traffic cases where blood specimens were sent to the state toxicology lab for testing Cases with records that could be matched across datasets. April 2013-December 2014	WSP Toxicology WSP Computer Automated Dispatch

Variables

Drug types and blood level coding

Drugs detected in blood, and their concentrations, were obtained from the Washington toxicology (TOX) dataset[1]. The laboratory indicates that they can detect approximately 125 substances[2]. THC was coded as present or absent based on THC levels being at or above 2ng/mL for time trend analyses. For descriptive analyses involving collision and violations types, THC was recoded into three groups: 1) not present or below detection threshold of 2 ng/mL; 2) 2.0 through 4.9 ng/mL; and 3) 5 ng/mL or higher (at or above *per se* limit). For binary analyses, we categorized ethanol (alcohol) as present or absent based on a detection

[1] For most years the level of reporting was 1 ng/mL, however there was a period from December 3, 2012 through May 8, 2014 where the reporting limit for THC was 2 ng/mL. For temporal comparability, cases below 2 ng/mL for THC were coded as 0.

[2] http://www.wsp.wa.gov/forensics/docs/toxicology/Measurement_Uncertainty/drug_list_uncertanty_values.pdf

threshold of 0.01 g/dL. For descriptive analyses involving collision and violation type analyses, alcohol was recoded into three groups: 1) not present or below detection threshold of 0.01 g/dL; 2) 0.010- 0.079 g/dL; and 3) 0.08 g/dL or greater (at or above *per se* limit). Other potentially intoxicating drugs were aggregated into a single category, regardless of the blood level; these included prescription and non-prescription opioids, methamphetamine, cocaine and benzodiazepines. Non-intoxicating drugs such as selective serotonin re-uptake inhibitor anti-depressants were not incorporated into the drug categorization scheme and were not considered in analyses. From 2005 to 2012, blood testing procedures at the WSP laboratory varied, based primarily on the presence and level of alcohol, with the result that many cases positive for alcohol did not undergo further testing for other substances. Longitudinal analyses therefore are confined to the smaller subset of suspected DUI cases for which blood alcohol was not detected to maximize comparability over time.

Driving violation types

From the WSP TARs dataset, up to three different violations were recorded. Because these data were used in combination with CAD, data from April 2013 through December 2014 were utilized. Violation codes from TARs (n=130) were aggregated into any moving violation or non-moving violations. Cases for which the only violation codes were for DUI, with no information about observed driving violation types, were excluded because the intent was to document events that led to a suspicion of DUI. The police-reported collision type was obtained from the CAD dataset. Fatal and injury collisions were considered as one category; and non-injury collisions as a separate category.

Demographic Description of Drivers

Age was based upon the driver date of birth as recorded in the TOX dataset. Driver gender was also obtained from the TOX data. Ethnicity was that perceived and reported by the officer and was obtained from the TARs dataset. For logistic regression analyses race was coded as white/non-white. Hispanic was reported separately from white and coded as non-white.

Other variables

Road type was obtained from the TARs dataset and was recorded as an interstate, state, or county/city road. Contact type was recorded by the officer in the TARs system. Contact hour was the first recorded time associated with a case, which was obtained from the CAD dataset, this could have been when dispatch notified an officer of an incident or an officer notified dispatch of an incident. County type was assigned based on the county of the offense as recorded in the TOX dataset per the US Office of Management and Budget (OMB) classification system of metropolitan, micropolitan or outside of the Core Based Statistical Area – which covers all other areas [3].

[3] Metropolitan = counties or cities or urbanized areas with over 50,000 persons; and some counties in which at least 50 percent of the population resides in an Urbanized Area or counties meeting a complex set of conditions based on commuting patterns and population density. Micropolitan = counties with urban clusters of 10,000 to 49,999 persons; and some counties in which at least 50 percent of the population resides in an Urbanized Area or counties meeting a complex set of conditions based on commuting patterns and population density. Outside CBSA = Outside Core Based Statistical Area - covers all other areas.

Dataset linkage processes (Objectives 2-4)

The dataset linkage was a multi-step process. The TOX dataset included Washington drivers suspected of a DUI infraction and/or involved in a traffic collision. The CAD dataset was linked to the TOX dataset by the WSP agency number and date of offense and cases were retained if there was at least one reference to blood in the CAD dataset. We linked TARs data to the resulting TOX/CAD dataset by linking the officer badge number, incident date and time, and suspect's gender and age.

The CAD dataset did not contain time stamped entries related to the exact time of the blood draw. Rather, data entries in the CAD dataset typically referenced a specific evidence number connected to the process of arranging for a blood specimen and a time stamp was associated with this reference. An algorithm was developed based upon text string searches of the CAD to create an ETBD. For 10 percent of cases, the word "blood" was not specifically associated with an evidence number and after a careful review of the data we determined that for this subset of cases we would utilize the time stamp associated with the first reference to "blood". As an initial assessment of the validity of the ETBD we pulled 25 random cases where the driver was positive for carboxy-THC but not for active THC and an additional 25 cases where the driver was positive for THC. We reviewed the complete sequence of activity reported in CAD for these 50 cases. Specifically, we looked in CAD for references to arriving and leaving the hospital (where the vast majority of blood draws occur) and found that using the first reference to blood coincided closely with the mid-point between hospital arrival time and hospital discharge time and therefore was a reasonable proxy to use for ETBD.

The University of Washington Human Subjects Division reviewed and approved all study procedures.

Results

Objective 1 - Documentation of law enforcement staffing and training, arrests, policies and procedures

Major policy and procedural changes in WA State

Major policy and procedural changes in WA State are outlined in Table 4 below. In 2009 Advanced Roadside Impaired Driving Enforcement (ARIDE) training began with almost all WSP field officers trained by 2013; the two-day course provides training on identifying impairment from alcohol and drugs that is more intensive than the standardized field sobriety test training and less intensive than the training required to become a Drug Recognition Expert. The impact of having officers ARIDE-trained is likely to increase officers' ability to detect impairment. Initiative 502 passed in November 2012 with the WSP FLSB expanding blood testing by January 2013, essentially testing all specimens for a broad array of drugs whereas previously many specimens positive for ethanol at higher levels, typically 0.08 g/dL, would not automatically be tested for other drugs. In April of 2013 the Missouri v. McNeely court opinion was issued which essentially required a warrant for DUI related blood tests. Retail marijuana stores began opening in July of 2014.

Interviews with law enforcement officers indicated that they were aware that THC metabolized quickly, and they were aware of the McNeely decision and the impact on requiring a warrant for obtaining blood. Further the officers generally agreed that the average time to obtain a blood draw was approximately two and a half hours.

Table 2- Major DUI related policy and procedural changes in WA State from 2005-2014

Date	Change
2009	Advanced Roadside Impaired Driving Enforcement (ARIDE) Training begins for WSP, virtually all are trained by 2013.
November 2012	Initiative 502 Passes
January 2013	WSP Toxicology Laboratory begins testing all specimens for broader array of substances.
April 2013	Missouri v. McNeely U.S. Supreme Court opinion issued. Generally requires warrant for blood tests.
July 2014	Retail cannabis stores begin opening.

For context, data on overall WSP commissioned staffing, training, and DUI arrests by year are provided in Table 3. Overall the number of DUI arrests went down and the number of officers trained in Advanced Roadside Impaired Driving Enforcement (ARIDE) increased substantially. Drug Recognition Experts (DRE) receive two weeks of advanced training on identifying and evaluating impaired driving and they may be called to the scene of a suspected DUI to conduct an evaluation of impairment. DRE evaluations appear to have dropped substantially in 2013, perhaps due in part to the increase in ARIDE-trained officers and their understanding of the importance of blood test results and timely blood draws. The number of DRE cases with blood evidence submitted declined from 2011-2014. The number of field officer troopers assigned to traffic enforcement peaked in 2008 and was at its lowest level in 2013 and 2014. Overall, there appears to have been a decline in the number of WSP officers assigned to traffic just as there was a substantial increase in the

number of ARIDE-trained officers: the number of traffic officers declined about 10 percent, but the number of all officers that were ARIDE-trained increased substantially. Note that the number of ARIDE-trained officers is cumulative so it exceeds the number of WSP field officers assigned to traffic in a given year.

Table 3- DUI Court Filings and Arrests & WSP Staffing, 2005-2014

	Source	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
GENERAL INFO											
Total State Population *in millions*	OFM - website	6.3	6.4	6.5	6.6	6.7	6.7	6.8	6.8	6.9	7.0
Licensed Drivers *in millions*	WSDOT - Annual Collision Reports	n.a.	4.8	4.9	5.0	5.1	5.1	5.2	5.1	5.2	n.a.
DUI-Related Court Filings (Proxy for Arrests)											
Misdemeanors Filed in District (County)/Municipal Courts - aka "Courts of Limited Jurisdiction"	AOC website- reports	41872	42,029	41,569	39,455	41,006	38,191	38,024	34,701	31,730	28,588
Felonies filed in Superior Court	AOC- JIS request	1124	1150	1288	1371	1295	1092	1099	1031	1069	987
Total DUI-Related Cases Filed in Courts	Sum of above	42,996	43,179	42,857	40,826	42,301	39,283	39,123	35,732	32,799	29,575
WSP DUI -Related Arrests											
Total DUI Related Arrests	WSP Special Analysis	n.a.	40,829	42,408	39,632	40,071	39,185	39,833	37,748	34,264	30,622
WSP STAFFING											
Full Time Equivalents-Field Office Troopers assigned to traffic	WSP - public disclosure request	620	647	643	657	626	607	600	626	590	594
DRE trained officers in the state	WSP Special Analysis	182	186	195	211	225	240	234	210	205	n.a.
DRE Evaluations Conducted	WSP Special Analysis	1,508	1,534	1,426	1,415	1,410	1,532	1,573	1,420	982	n.a.
DRE cases with blood evidence submitted	WSP Toxicologist	1,322	1,411	1,265	1,194	1,167	1,223	1,252	1,027	857	706
ARIDE trained officers in the state	WSP Public disclosure request & special analysis	n/a	n/a	n/a	n/a	109	238	327	463	669	703

OFM= Office of Financial Management; WSDOT= WA State Dept. of Transportation; AOC = Administrative Office of the Courts; JIS = Judicial Information System

DUI case flow and data processing

A graphical overview of the procedures involved in a DUI traffic stop is included in Figure 1 in the Appendix. The figure depicts the multiple decision points that can be encountered during a typical traffic stop.

Objective 2 - Longitudinal analyses of THC-positive cases

The sequence and number of cases removed during exclusion processes for longitudinal analyses from 2005-2014 for toxicology cases are described in Table 4 below.

Table 4 - Study inclusion and exclusion- Objective 2 Sample: Toxicology Longitudinal Sample (2005-2014)

N Total Cases	%	Description	N Cases Removed
104,108	100%	Data provided by WSP FLSB laboratory Excluded: Drug investigation, Liquor control board and sex abuse cases	-
98,577	95%	Removed Non-WA State Cases (OR, AK, ID) and DRE training cases	5,531
54,662	53%	Removed Death Investigations that were not Traffic Accident Fatality with Manner of Death = accident.	43,915
54,662	100%	**DATASET: TOX cases for 2005-2014 analyses**	

Description of the Number and Proportion of Suspected DUI and Collision Blood Tests Positive for Alcohol and Cannabis

The graphs that follow show the number of DUI and collision cases as well as the proportions of cases positive for different substances of interest. Counts per year are shown to give a sense of absolute scale, and proportions are shown to give both a sense of relative scale as well as to identify possible changes in detection of suspected DUIs over time. It is not possible to definitively determine the cause of changes over time.

Specimens Positive for Alcohol Among All DUI Cases Tested by Toxicology

Data from the WSP FLSB for suspected DUIs with blood evidence submitted for toxicology tests in the state, including WSP and local jurisdictions, indicate that the total number of cases submitted began slowly increasing in 2009 with a substantial increase in 2014 to 6,363 of which 51 percent were positive for alcohol. The proportion of cases positive for alcohol appears to be slightly greater in 2014 than in prior years. Over the same period, total DUI arrests and DUI court cases each decreased (Table 3).

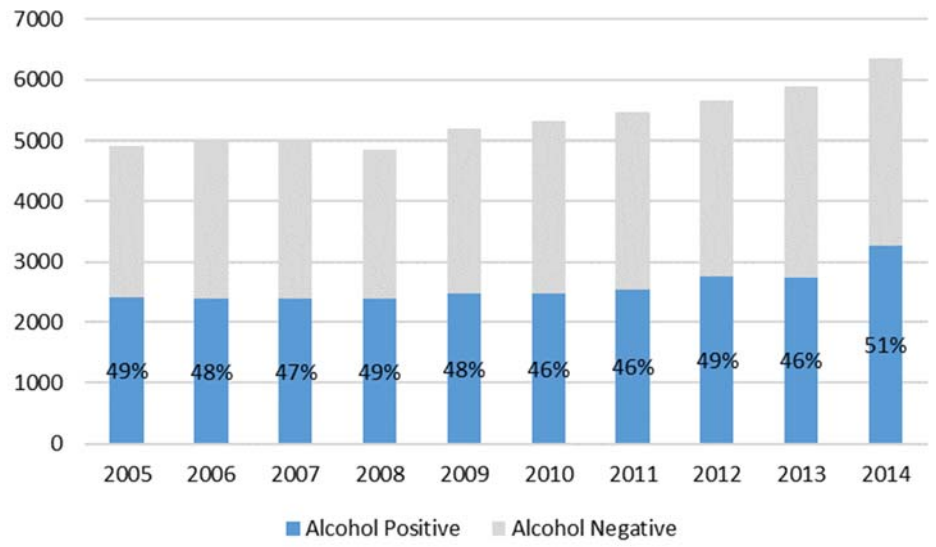
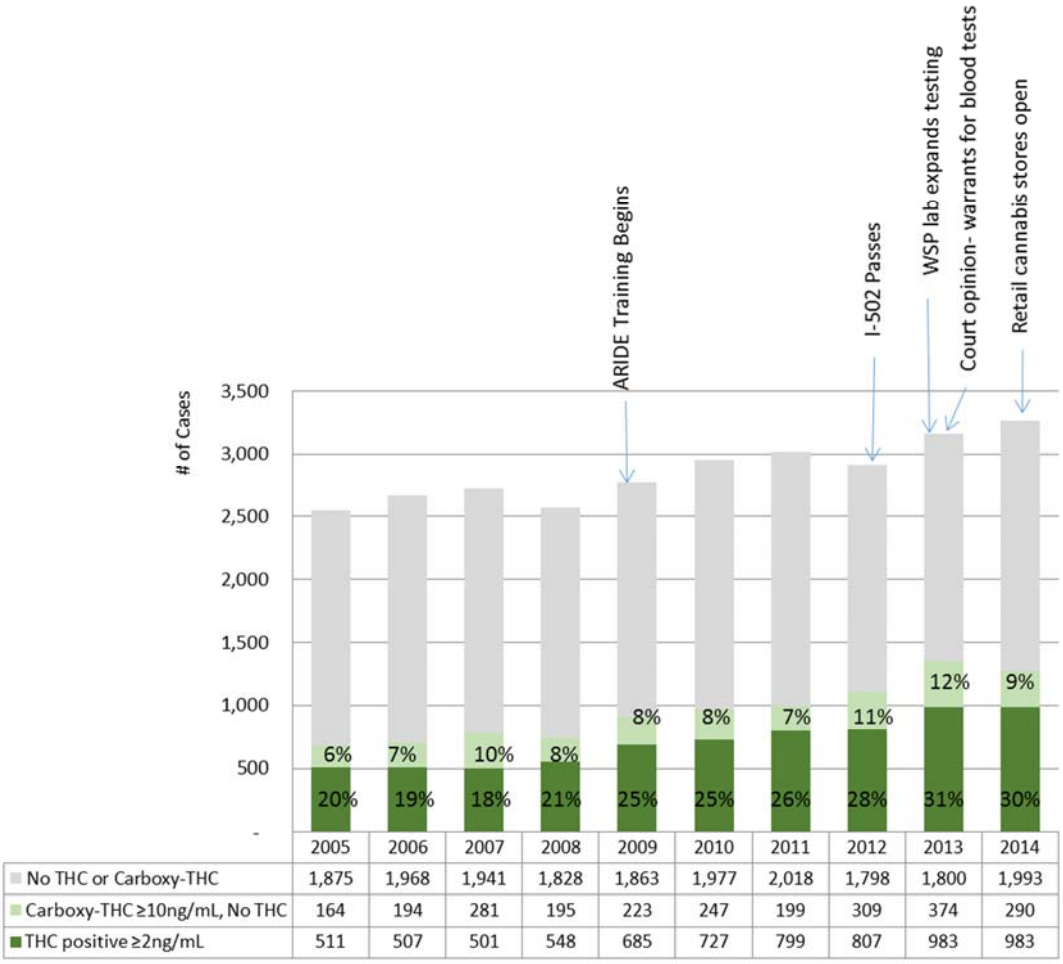


Figure 2- Collisions and Suspected DUI Cases Tested by Toxicology

Specimens Positive for THC Among Alcohol-Negative DUI and Collision Cases

Figure 3 excludes all DUI cases sent to the laboratory that were positive for alcohol so that trends could be measured despite changes in laboratory testing procedures in 2013. From 2005 through 2014 the proportion of DUI cases excluding those positive for alcohol that were positive for THC at a level of 2ng/mL or greater increased from 20 percent to 30 percent, a 50 percent relative increase in the proportion, and the number nearly doubled from 511 to 983. Note that excluding cases with THC levels below 2ng/mL removed up to 10 percent of THC-positive cases in years in which the reporting limit was 1ng/mL; for instance, there were 51 cases in 2005 with THC levels between 1-2ng/mL. The total number of DUI cases sent to the laboratory that were negative for alcohol appear to have gradually increased from 2009 to 2014 from 2771 to 3266. The timing of major training, legal and procedural changes are shown in Figure 3 and described earlier in the results.



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
No THC or Carboxy-THC	1,875	1,968	1,941	1,828	1,863	1,977	2,018	1,798	1,800	1,993
Carboxy-THC ≥10ng/mL, No THC	164	194	281	195	223	247	199	309	374	290
THC positive ≥2ng/mL	511	507	501	548	685	727	799	807	983	983

Figure 3- Collisions and Suspected DUI Cases Tested by Toxicology Negative for Alcohol & Timing of training, legal and procedural changes

The median THC level varied by year, ranging from 4.0 to 6.6 ng/mL. A test of the trend over time in the median THC level indicated a statistically significant increase from 2005 to 2014, with an average annual increase of 0.18ng/mL per year (p=0.015, 95 percent C.I. 0.04-0.32) (Table 5).

Table 5- Median level of THC among collisions and suspected DUI cases tested by toxicology negative for alcohol

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
THC Positive ≥2ng/mL	511	507	501	548	685	727	799	807	983	983
Median THC Level	4.0	4.6	4.8	5.15	6.1	5.5	5.4	6.6	5.5	5.6

Tests of Trends in THC-Positive Cases Over Time

Statistical tests of change over time in the prevalence of those positive for THC with or without other drugs among those with blood evidence submitted, excluding those positive

for alcohol, indicate a significant average annual increase of 1.43 percent per year (95% C.I.: 1.26%-1.60%) from 2005-2014. For each year the prevalence difference indicates whether the prevalence increased or decreased compared to the reference year of 2005. In 2014 there was a 10.06 percent increase in the absolute prevalence of THC-positive cases compared to 2005. (Table 6).

Table 6- Trends in THC-positive drivers among collisions and suspected DUI cases tested by toxicology, excluding cases positive for alcohol, WA State, 2005-2014

Year	All DUI Tests, Negative for Alcohol	THC-Positive	Prevalence (%)	Prevalence Difference (%)	95% CI
Trend by Year				1.43	(1.26,14.60)
2005	2550	511	20.04	*Reference*	
2006	2669	507	19.00	-1.04	(-3.19, 1.11)
2007	2723	501	18.40	-1.64	(-3.77, 0.49)
2008	2571	548	21.31	1.28	(-0.94, 3.49)
2009	2771	685	24.72	4.68	(2.45, 6.92)
2010	2951	727	24.64	4.60	(2.40, 6.79)
2011	3016	799	26.49	6.45	(4.24, 8.67)
2012	2914	807	27.69	7.65	(5.41, 9.90)
2013	3157	983	31.14	11.10	(8.86, 13.34)
2014	3266	983	30.10	10.06	(7.85, 12.27)

Statistical tests of change over time in the count of those positive for THC only among all of those tested for drugs indicate a significant increase overall of 1.32 percent (95% CI: 1.18%-1.47%) from 2005-2014 (Table 7). In 2014, there was a 9.64 percent increase in the prevalence of THC-positive (no other drugs) cases compared to 2005.

Table 7- Trends in THC-only-positive collisions and suspected DUI cases tested by toxicology, excluding cases positive for alcohol, WA State, 2005-2014

Year	All DUI Tests, Negative for Alcohol	THC-Positive (No other drugs)	Prevalence (%)	Prevalence Difference (%)	95% CI
Trend by Year				1.32	(1.18, 1.47)
2005	2550	321	12.59	*Reference*	
2006	2669	324	12.14	-0.45	(-2.24, 1.34)
2007	2723	327	12.01	-0.58	(-2.35, 1.19)
2008	2571	381	14.82	2.23	(0.35, 4.11)
2009	2771	500	18.04	5.46	(3.53, 7.38)
2010	2951	493	16.71	4.12	(2.26, 5.98)
2011	3016	576	19.10	6.51	(4.61, 8.41)
2012	2914	602	20.66	8.07	(6.12, 10.02)
2013	3157	739	23.41	10.82	(8.86, 12.78)
2014	3266	726	22.23	9.64	(7.72, 11.56)

Trends tests for THC before and after I-502

There was evidence that the slope of change in THC-positivity (i.e., proportion tested positive for THC among all alcohol-negative DUI cases tested) differed before and after I-502 adoption; this was judged by the statistical significance of the interaction term between I-502 adoption and time in binomial regression models. While there was an overall upward trend in THC-positivity during the entire period of time from 2005 through 2014, the slope of was greater prior to I-502 adoption than that after I-502 adoption (difference in slopes: 2.3%; 95% CI: 0.1, 4.6%). Results were consistent when analyses were restricted to those who were THC-positive only (difference in slopes: 6.4%; 95% CI: 4.0%, 8.9%).

Objective 3 - THC and other substances detected in drivers suspected of DUI or involved in collisions

The linking process of TOX, CAD, TARS, inclusion/exclusion criteria, and the number of cases included in the analyses of cases from April 2013 through December 2014 are detailed in Table 8 below.

Table 8- Study inclusion and exclusion- Linked Datasets (April 2013-December 2014)

N Total Cases	%	Description	N Cases Removed
22,844	**100%**	Obtained WSP FLSB laboratory toxicology cases	-
21,835	96%	Removed Non-WA State Cases (OR, AK, ID)	1,009
18,293	80%	Removed cases that did not have "blood" or "serum" in the text string for evidence type	3,542
11,964	52%	Removed Death Investigations that were not Traffic Accidents & Traffic Fatalities	6,329
11,955	52%	Removed Traffic Fatalities where the Manner of Death ≠ Accident" *(so were a traffic fatality – but caused by something like a seizure or heart attack or suicide –carbon monoxide)*	9
11,779	52%	Removed cases where the individual was clearly not the driver	176
11,756	51%	Removed cases when the vehicle involved was clearly not a road vehicle	23
11,756	**100%**	**DATASET: TOX cases –exclusion criteria fully applied – To be linked w/ CAD**	
5,144	44%	Removed non WSP (local law enforcement) cases in TOX	6,612
5,123	44%	Removed WSP cases with missing WSP agency case #	21
5,100	43%	Remove duplicate cases with same WSP agency case #	23
4,426	38%	Removed TOX cases w. offence date in Jan, Feb or Mar 2013 *(CAD data unavailable for that period)*	674
3,867	33%	Removed TOX cases that could not be matched w/ CAD using WSP agency case #	559
3,866	33%	Removed DI cases where could not confirm decedent from CAD was a driver.	1
3,866	**100%**	**DATASET: TOX/CAD cases to be linked with TARS**	
2603	67%	Removed all cases that did not match with TARS based on (1) exact match of officer's badge number; (2) incident date/time difference range between 65 to 120 minutes (CAD minus TARS); (3) exact match on suspect's gender; (4) suspects age ± 1	1263
2602	67%	Removed all cases with no violation information in TARS record	1
2588	67%	Removed all cases identified in TARS as "other collision"	14
2213	57%	Removed all cases identified in TARS with DUI as only case type	375
2213	**100%**	**DATASET: TOX/CAD/TARs cases to be used in Objective 3 & 4 Analyses**	

Case Types: DI = Death Investigation; DUI = Driving Under the Influence; DRE = Drug Recognition Expert involved

WSP Toxicology receives all blood specimens obtained from traffic accidents/violations (suspected DUIS) statewide. Not just those ordered by WSP officers.

CAD – The CAD (Computer aided dispatch) TARS – Target Activity Reporting System

Analyses of WSP cases for which toxicology, dispatch and officer time and activity records were linked were analyzed to examine the relationship between collision severity and the presence of THC at 2 ng/mL or greater. Collision severity was divided into two groups, based on police-reported categories: 1) fatal collisions or collisions where an injury was reported; and 2) non-injury collisions.

Among collision-involved drivers whose blood was tested for potentially impairing substances, 58 percent were involved in fatal/injury collisions, and 42 percent were involved in non-injury collisions. Overall, 4 percent of drivers involved in collisions tested positive for THC and negative for alcohol and other potentially impairing drugs and an additional 11 percent were positive for THC as well as alcohol or another potentially impairing drug (Table 9). Among this group, 7 percent had a THC level of 5ng/mL or higher and 53 percent had a blood alcohol level of at least 0.08 g/dL.

Table 9- Characteristics of collision-involved drivers with blood evidence submitted to the Washington State Patrol Forensic Laboratory Services Bureau, April 2013 – December 2014

	Fatal/Injury Collisions		Non-Fatal/Injury Collisions		TOTAL	
	#	%	#	%	#	%
Gender						
Male	306	72%	209	69%	515	71%
Female	121	28%	94	31%	215	29%
Age						
Age (mean, sd)	37	14.15	40	14.05	38	14.16
Age Groups						
<18	5	1%	3	1%	8	1%
18-20	31	7%	14	5%	45	6%
21-30	138	32%	75	25%	213	29%
31-40	78	18%	71	23%	149	20%
41-50	81	19%	61	20%	142	19%
51-60	69	16%	50	17%	119	16%
60-69	21	5%	24	8%	45	6%
70+	4	1%	5	2%	9	1%
Ethnicity/Race						
White	329	77%	252	83%	581	80%
African American	17	4%	17	6%	34	5%
Native American	19	4%	11	4%	30	4%
Asian Pac. Islander	10	2%	7	2%	17	2%
East Indian	4	1%	0	0%	4	1%
Hispanic	42	10%	14	5%	56	8%
Other	6	1%	2	1%	8	1%
Alcohol present						
No Alcohol	115	27%	163	54%	278	38%
0.01-0.07	48	11%	18	6%	66	9%
≥ 0.08	264	62%	122	40%	386	53%
Other potentially intoxicating drugs present						
No	275	64%	149	49%	424	58%
Yes	152	36%	154	51%	306	42%
Carboxy-THC present						
No	312	73%	227	75%	539	74%
Yes	115	27%	76	25%	191	26%
Δ^9-THC present						
THC not present	362	85%	259	85%	621	85%
THC 2-4.9 ng/mL	36	8%	24	8%	60	8%
THC 5+ ng/mL	29	7%	20	7%	49	7%
Δ^9-THC only drug present						
No	414	97%	285	94%	699	96%
Yes	13	3%	18	6%	31	4%
Δ^9-THC + alcohol or other pot. intoxicating drug present						
No	375	88%	277	91%	652	89%
Yes	52	12%	26	9%	78	11%
TOTAL	427	100%	303	100%	730	100%

Driving Violation Type and THC

Among the group of drivers for whom blood testing was conducted due to suspected impairment, we examined the nature of the initial driving violations leading to the traffic stop. For this analysis, we dichotomized violations into: 1) moving violations (e.g. speeding, lane change); and 2) non-moving violations (e.g. equipment). A hierarchical approach to coding the violation type was utilized so cases with any of the up to three violation types coded as a moving violation were considered a moving violation case.

For those with moving or non-moving violations, but no collision, 26 percent tested positive for THC but not other drugs or alcohol, and 11 percent tested positive for THC and alcohol or another potentially intoxicating drug. Among this group that was not involved in a collision, 20 percent had a THC level of at least 5 ng/mL and 30 percent had an alcohol level of at least 0.08 g/dL (Table 10).

Table 10- Characteristics of drivers suspected of DUI with evidence submitted to the Washington State Patrol Forensic Laboratory Services Bureau, April 2013 – December 2014

	Moving Violation		Non-Moving Violation		TOTAL	
	#	%	#	%	#	%
Gender						
Male	877	76%	258	77%	1135	77%
Female	271	24%	77	23%	348	23%
Age						
Age (mean, sd)	34	13.53	33	12.98	34	13.42
Age Groups						
<18	15	1%	15	4%	30	2%
18-20	197	17%	59	18%	256	17%
21-30	349	30%	99	30%	448	30%
31-40	232	20%	66	20%	298	20%
41-50	178	16%	57	17%	235	16%
51-60	126	11%	31	9%	157	11%
60-69	44	4%	5	1%	49	3%
70+	7	1%	3	1%	10	1%
Ethnicity/Race						
White	829	72%	238	71%	1067	72%
African American	81	7%	23	7%	104	7%
Native American	56	5%	19	6%	75	5%
Asian Pac. Islander	27	2%	7	2%	34	2%
East Indian	3	0%	0	0%	3	0%
Hispanic	143	12%	48	14%	191	13%
Other	9	1%	0	0%	9	1%
Alcohol present						
No Alcohol	729	64%	221	66%	950	64%
0.01-0.07	74	6%	20	6%	94	6%
≥ 0.08	345	30%	94	28%	439	30%
Other potentially intoxicating drugs present						
No	769	67%	215	64%	984	66%
Yes	379	33%	120	36%	499	34%
Carboxy-THC present						
No	595	52%	174	52%	769	52%
Yes	553	48%	161	48%	714	48%
Δ^9-THC present						
THC not present	731	64%	211	63%	942	64%
THC 2-4.9 ng/mL	181	16%	64	19%	245	17%
THC 5+ ng/mL	236	21%	60	18%	296	20%
Δ^9-THC only drug present						
No	856	75%	242	72%	1098	74%
Yes	292	25%	93	28%	385	26%
Δ^9-THC + alcohol or other pot. intoxicating drug present						
No	1023	89%	304	91%	1327	89%
Yes	125	11%	31	9%	156	11%
TOTAL	1148	100%	335	100%	1483	100%

Objective 4- Analysis of estimated time to blood draw and THC levels

The number of cases positive for any THC (with or without carboxy-THC or other substances) and those positive for carboxy-THC (no THC), are displayed in the Figure 4 below for the period from April 2013 through December 2014. There are many more cases positive for THC (n=948) than carboxy-THC (no THC) (n=440). There is a significant difference in the median ETBD with THC-positive cases having a significantly shorter median time of 139 compared to 175 minutes for carboxy-THC (no THC) (p<0.001).

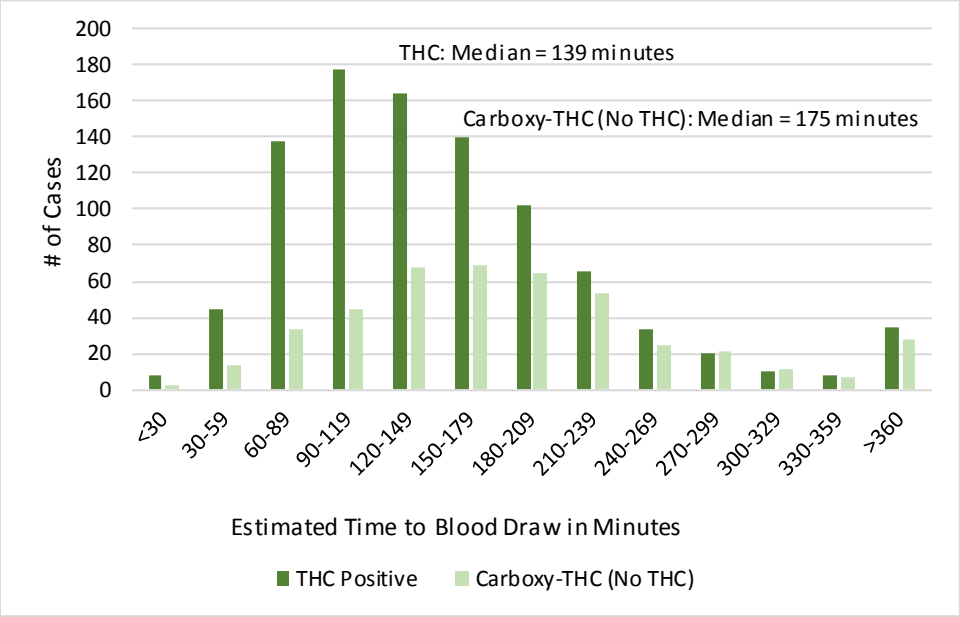


Figure 4- Estimated Time to Blood Draw for Collisions and Suspected DUIs

The median ETBD and statistical tests of differences are displayed in Table 11 below. The median ETBD for all other substances was 174 minutes, statistically no different than cases positive for carboxy-THC (no THC), while the median for THC-positive cases was 139 minutes, much less than for other substances.

Table 11- Estimated time to blood draw for collisions and suspected DUI cases in WA State, April 2013 – December 2014

	Cases	Median estimated time in minutes	Time difference from carboxy-THC (no THC)	p-value
Carboxy-THC (no THC) ≥10ng/mL	440	175	--	--
THC ≥2ng/mL	948	139	36	<0.001
All other substances	2249	174	1	0.871
All cases	**3637**	**165**	**10**	**…**

The proportion positive for THC at a level of 5ng/mL or greater is compared for ETBD less than and greater than two hours in Figure 5. The proportion of those with an ETBD of less

than 2 hours who had a THC blood level greater than or equal to 5ng/mL was 26 percent compared to 10 percent for those with an ETBD of 2 hours or more ($p<0.001$).

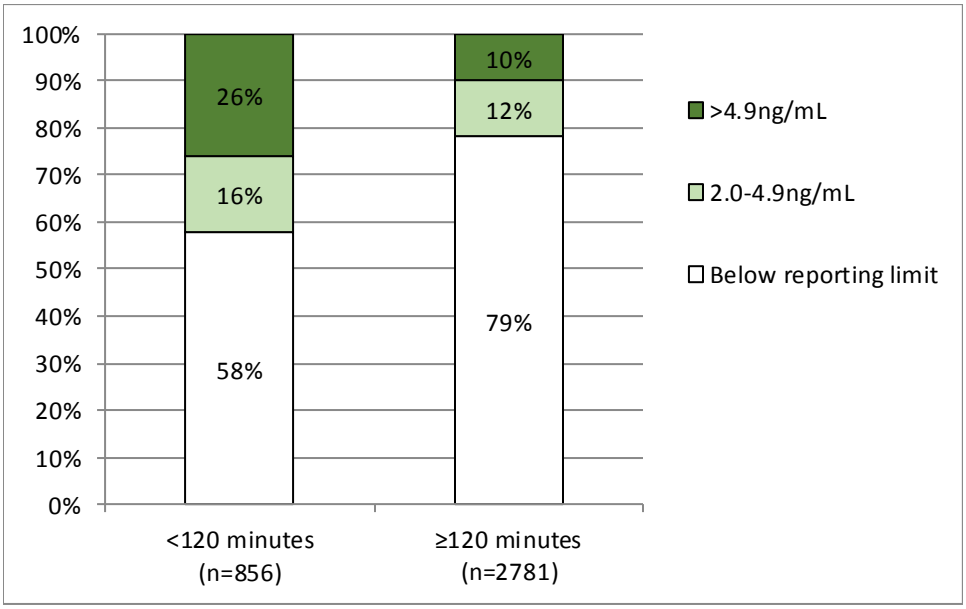


Figure 5 - THC Level by Estimated Time to Blood Draw

Among drivers who had THC present at a level of 2ng/mL or higher, we examined the relationship between measured THC level and ETBD. Figure 6 indicates that THC levels are negatively associated with ETBD, with a lower blood level of THC on average the greater the ETBD. This would be expected at the population level because it is related to the phenomenon in humans that drugs are metabolized over time and blood levels therefore decline. The line displayed is a locally weighted regression line which fits the data better than a simple trend line which would assume that the relationship between the variables is constant over time. The changing slope of the line suggests that the relationship is different across time.

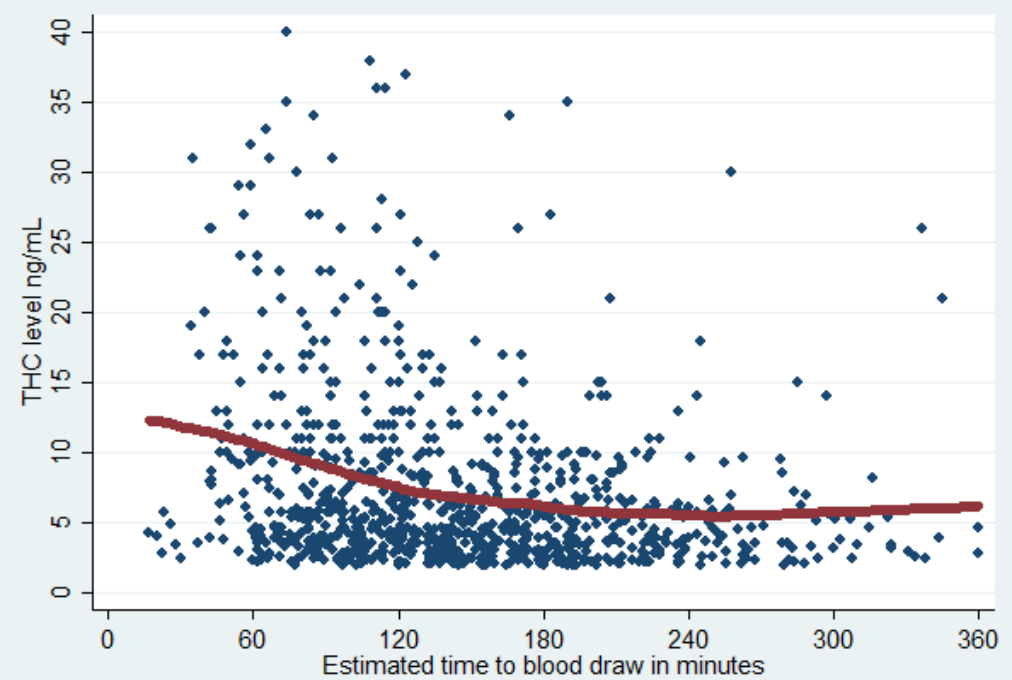


Figure 6- THC level by Estimated Time to Blood Draw- Scatter plot with locally weighted regression line

Regression analyses indicate that for every additional minute of time until blood draw the THC level declines 0.0228 ng/mL on average (95% C.I. -0.0291 to -0.0164; p-value<0.0001). During the first two hours of ETBD, the regression coefficient can be interpreted as indicating that on average there is a decline in the THC level detected of 5.328 ng/mL over 120 minutes.

We conducted stratified analyses to compare change in measured THC blood levels in two periods: 0-2 hours ETBD, and 2-4 hours ETBD. For those with an ETBD less than 2 hours there was a significant negative association between ETBD and THC level of -0.0444 (95% C.I. -0.0796 to -0.0165, p-value= 0.014). However, for those with an ETBD between 2-4 hours there was not a significant relationship between ETBD and THC level -0.0077 (95% C.I. -0.0158 to 0.0004, p-value = 0.062).

For these analyses, cases with ETBD that were negative (n=4) or zero (n=5) were excluded. Scatterplots and regression analysis excluded cases with ETBD above 6 hours (4 percent of cases) and one case with an extremely high THC level of 100.

Discussion of the importance of estimated time to blood draw

Analysis of the ETBD indicates that cases positive for THC have a median ETBD that is 36 minutes shorter than for carboxy-THC (no THC) present. These findings indicate the importance of time to blood draw and the fact that accounting for blood time would appear to be essential to properly conduct analyses of the presence of THC in suspected DUI cases. Interpreting results across studies with different blood draw procedures and timing e.g. a roadside survey with a phlebotomist on site, should carefully account for ETBD.

Limitations

This study had a number of important limitations. First, because of the rapid metabolism of active THC and the challenges law enforcement officers face in timely obtainment of blood specimens, an unknown proportion of carboxy-THC-positive drivers at the time of the collision or traffic stop may have had quantifiable THC levels. Therefore, estimates of THC-involved driving based upon blood toxicology results may underestimate THC levels at the time of first contact with police or collision.

Second, laboratory procedures changed over time for the cut points for reporting of THC and carboxy-THC. In addition, in 2013 the laboratory instituted changes that led to all collisions and suspected DUI cases being tested for a broad array of drugs. As a result of these changes, the data sets analyzed had to be narrowed down to be comparable over time for the trend analyses in Objective 2. These procedures were important to ensure that accurate and fair comparisons were made over time. However, the use of these smaller datasets mean that they are not representative of all cases received and need to be interpreted carefully. In particular, the exclusion of alcohol involved cases for trend analyses introduces important limitations: the number of cases in which THC was involved is larger than the number in these restricted analyses and trends in THC use in combination with alcohol cannot be examined. In other analyses (objectives 3 and 4) we restricted analyses to data from April 2013 through 2014 during which all blood specimens were tested for alcohol and other potentially impairing drugs.

Third, multiple research studies indicate that regular users of cannabis become tolerant to some of the impairment associated with THC [10,28]. At present there is no way to definitively identify whether a person is a regular, occasional or novice user from toxicological data alone, and impairment cannot be inferred based solely on blood THC concentration.

Fourth, ETBD data were not available for the entire period of longitudinal analyses, therefore it is possible that changes in ETBD were associated with the longitudinal patterns of increasing proportion of cases positive for THC and the increasing median THC over time.

Fifth, the sample was limited to WSP cases for which the variables of interest were available and to cases that could successfully be linked. To the degree that these selected cases may not be representative of all DUI cases, it may not be appropriate to generalize these to all WSP cases and is unlikely to be representative of local law enforcement cases given the different types of cases and locations with which they typically work.

The approach utilized in these longitudinal analyses, excluding cases positive for ethanol, is different than that taken in the published paper by Couper and Peterson (2014). They examined trends over time and for historical data estimated the proportion of cases, extrapolating from a sub-analysis of previous testing results from 2008 that were only tested for ethanol that might have been positive for THC. Because laboratory testing procedures for which cases received comprehensive testing changed substantially around the time of the passage of I-502 we chose to conduct a restricted analysis rather than make assumptions about the prevalence of THC in historical cases.

Conclusion

Data indicate increases in the proportion of DUI cases involving THC and an increase in the median level of THC in cases from 2005-2014, however there was no significant additional increase related to the passage of I-502 in 2012. Among drivers in collisions, the majority (53%) were alcohol-impaired at a level of 0.08 g/dL or higher and 7 percent met or exceeded the *per se* level of THC, 5ng/mL. Drivers suspected of DUI in the absence of a collision were most commonly under the influence of alcohol, 30 percent, at 0.08 g/dL or above, and 20 percent had a THC level of 5ng/mL or above. Overall the average ETBD was 165 minutes. These findings indicate that THC-positive driving is relatively common in Washington, appears to be increasing and is likely underestimated given the generally protracted time until a blood specimen is obtained. Evaluating the impact of time until blood draw is complicated by the lack of available standardized law enforcement data on the time of specimen collection. Additional officer training to detect impaired driving, and the increase in targeted programs, paralleled much of the increase in THC involved cases even as DUI arrests declined.

There remain significant and meaningful delays between the initial encounter with law enforcement and the collection of blood evidence. The median estimated time to blood draw for THC-positive cases was 139 minutes and the average decline in THC levels was 5ng/mL during the first two hours following police contact. It is likely that the prolonged delay in blood testing routinely resulted in those who were above 5ng/mL at the time of a collision or driving violation being below this level at the time blood was drawn. These findings highlight the challenges in enforcing drugged driving laws, particularly with a *per se* component, in the absence of point-of-contact testing modalities and logistical delays in obtaining blood specimens.

The results of the qualitative and quantitative analysis are of particular value in that the secondary data are real world data from the Washington State Patrol. Documenting the actual time of the blood draw in a standardized manner that can be readily obtained from secondary datasets would be tremendously beneficial for examining the impacts of laws, policies and practices as well as providing important data for epidemiological studies. The findings regarding the limitations of these data have implications for improving data systems to better understand the nature of impaired driving cases and collisions associated with cannabis and other substances.

References

1. Hasin DS, Saha TD, Kerridge BT, et al. Prevalence of Marijuana Use Disorders in the United States Between 2001-2002 and 2012-2013. *JAMA Psychiatry*. 2015;72(12):1. doi:10.1001/jamapsychiatry.2015.1858.
2. *Medical Cannabis*. Washington State Legislature; 1999. http://app.leg.wa.gov/RCW/default.aspx?Cite=69.51A&full=true.
3. *Initiative Measure No. 502.*; 2011. http://lcb.wa.gov/publications/Marijuana/I-502/i502.pdf.
4. Healthy Youth Survey Fact Sheet, Cannabis Use for Washington State. http://www.askhys.net/FactSheets. Published 2015.
5. *Young Adult Health Survey- Cannabis.*; 2015. http://www.learnaboutcannabiswa.org/factsheets/YAHS Cannabis.pdf.
6. Substance Abuse Mental Health Services Administration. 2013-2014 National Survey on Drug Use and Health: Model-Based Prevalence Estimates. http://www.samhsa.gov/data/sites/default/files/NSDUHsaePercents2014.pdf. Published 2015.
7. Darnell AJ. *I-502 Evaluation Plan and Preliminary Report on Implementation.* Olympia; 2015. http://wsipp.wa.gov/ReportFile/1616/Wsipp_I-502-Evaluation-Plan-and-Preliminary-Report-on-Implementation_Report.pdf.
8. Verstraete AG, Legrand S-A, Vandam L, Hughes B GP. *Drug Use, Impaired Driving and Traffic Accidents, Second Edition.* Lisbon; 2014. http://www.emcdda.europa.eu/attachements.cfm/att_229259_EN_TDXD14016ENN.pdf.
9. Sewell RA, Poling J, Sofuoglu M. The effect of cannabis compared with alcohol on driving. *Am J Addict*. 2009;18(3):185-193. doi:10.1080/10550490902786934.
10. Battistella G, Fornari E, Thomas A, et al. Weed or wheel! FMRI, behavioural, and toxicological investigations of how cannabis smoking affects skills necessary for driving. *PLoS One*. 2013;8(1):e52545. doi:10.1371/journal.pone.0052545.
11. Ramaekers JG, Berghaus G, van Laar M, Drummer OH. Dose related risk of motor vehicle crashes after cannabis use. *Drug Alcohol Depend*. 2004;73(2):109-119. http://www.ncbi.nlm.nih.gov/pubmed/14725950.
12. Pacula RL, Kilmer B, Wagenaar AC, Chaloupka FJ, Caulkins JP. Developing public health regulations for marijuana: lessons from alcohol and tobacco. *Am J Public Health*. 2014;104(6):1021-1028. doi:10.2105/AJPH.2013.301766.
13. *Cannabis / Marijuana (Δ 9 -Tetrahydrocannabinol, THC).*; 2015. http://www.nhtsa.gov/people/injury/research/job185drugs/cannabis.htm.
14. Robbe H. Marijuana's impairing effects on driving are moderate when taken alone but severe when combined with alcohol. *Hum Psychopharmacol Clin Exp*. 1998;13(S2):S70-S78.

15. Verstraete AG, Legrand S-A, Vandam L, Hughes B, Griffiths P. *Drug Use, Impaired Driving and Traffic Accidents*. Lisbon, Portugal; 2014.

16. Sewell RA, Poling J, Sofuoglu M. The effect of cannabis compared with alcohol on driving. *Am J Addict*. 2009;18(3):185-193. doi:10.1080/10550490902786934.

17. Schwope DM, Bosker WM, Ramaekers JG, Gorelick DA, Huestis MA. Psychomotor performance, subjective and physiological effects and whole blood Δ^9-tetrahydrocannabinol concentrations in heavy, chronic cannabis smokers following acute smoked cannabis. *J Anal Toxicol*. 2012;36(6):405-412. doi:10.1093/jat/bks044.

18. Bosker WM, Kuypers KPC, Theunissen EL, et al. Medicinal Δ9-tetrahydrocannabinol (dronabinol) impairs on-the-road driving performance of occasional and heavy cannabis users but is not detected in Standard Field Sobriety Tests. *Addiction*. 2012;107(10):1837-1844.

19. Lenné MG, Dietze PM, Triggs TJ, Walmsley S, Murphy B, Redman JR. The effects of cannabis and alcohol on simulated arterial driving: Influences of driving experience and task demand. *Accid Anal Prev*. 2010;42(3):859-866. doi:10.1016/j.aap.2009.04.021.

20. Grotenhermen F, Leson G, Berghaus G, et al. Developing limits for driving under cannabis. *Addiction*. 2007;102(12):1910-1917.

21. Compton, RP B, A. *Drug and Alcohol Collision Risk*. Washington, DC; 2015.

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

23. Berning, A, & Smither, DD. (2014). Understanding the limitations of drug test information, reporting, and testing practices in fatal crashes. (Traffic Safety Facts Research Note. DOT HS 812 072). Washington, DC: National Highway Traffic Safety Administration.

24. Karschner EL, Swortwood MJ, Hirvonen J, et al. Extended plasma cannabinoid excretion in chronic frequent cannabis smokers during sustained abstinence and correlation with psychomotor performance. *Drug Test Anal*. June 2015. doi:10.1002/dta.1825.

25. Lemos NP, Ingle EA. Cannabinoids in postmortem toxicology. *J Anal Toxicol*. 2011;35(7):394-401. http://www.ncbi.nlm.nih.gov/pubmed/21871147. Accessed December 18, 2015.

26. Holland MG, Schwope DM, Stoppacher R, Gillen SB, Huestis MA. Postmortem redistribution of Δ9-tetrahydrocannabinol (THC), 11-hydroxy-THC (11-OH-THC), and 11-nor-9-carboxy-THC (THCCOOH). *Forensic Sci Int*. 2011;212(1-3):247-251. doi:10.1016/j.forsciint.2011.06.028.

27. Huestis MA, Henningfield JE, Cone EJ. Blood Cannabinoids. I. Absorption of THC and Formation of 11-OH-THC and THCCOOH During and After Smoking Marijuana. *J Anal Toxicol*. 1992;16(5):276-282. doi:10.1093/jat/16.5.276.

28. Bosker WM, Theunissen EL, Conen S, et al. A placebo-controlled study to assess Standardized Field Sobriety Tests performance during alcohol and cannabis

intoxication in heavy cannabis users and accuracy of point of collection testing devices for detecting THC in oral fluid. *Psychopharmacology (Berl).* 2012;223(4):439-446. doi:10.1007/s00213-012-2732-y.

Appendix

DUI case flow and data processing

A graphical overview of the procedures involved in a DUI traffic stop is included in Figure 1 below. The figure depicts the multiple decision points that can be encountered during a typical traffic stop.

Abbreviations - DUI flow diagram

EBT	= Evidentiary Breath Test-Machine used for estimating blood alcohol concentration from a breath specimen
DOL	= Washington State Department of Licensing
DUI	= Driving Under the Influence
DRE	= Drug Recognition Expert
FSTs	= Field Sobriety Tests (not standardized)
PBT	= Portable/Preliminary Breath Test instrument for estimating blood alcohol concentration from a breath specimen
SFSTs	= Standardized Field Sobriety Tests

Figure 1- Common DUI Traffic Stop Flow (next page)

Figure 1- Common DUI Traffic Stop Flow