Journal of Analytical Toxicology 2014;38:569–574
doi:10.1093/jat/bku090

The Prevalence of Marijuana in Suspected Impaired Driving Cases in Washington State†

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In December 2012, the possession and private use of limited quantities of marijuana and marijuana products became legal in the state of Washington. At the same time, the state's driving under the influence statutes were amended to include a *per se* level of 5 ng/mL delta^9-tetrahydrocannabinol (THC) in whole blood for drivers aged 21 years and older. The aim of this study was to assess the effect of marijuana legalization on the prevalence of marijuana in suspected impaired driving cases. The prevalence of both active THC and its metabolite carboxy-THC detected in such cases pre-legalization was compared with the prevalence post-legalization. In 2009–2012, the average yearly percentage of cases positive for THC and carboxy-THC was 19.1% (range: 18.2–20.2%) and 27.9% (range: 26.3–28.6%), respectively. In 2013, the percentages had significantly increased to 24.9 and 40.0%, respectively ($P < 0.05$). The median THC concentration over the 5-year period ranged from 5.2 to 6.3 ng/mL, with individual concentrations ranging up to 90 ng/mL. An average of 56% of cases were at or >5 ng/mL over the 5-year period. The prevalence of alcohol and the majority of other drugs in this same population of suspected impaired drivers submitted for testing did not change during this same 5-year period—marijuana was the only drug to show such an increase in frequency. Further, this observed increase remained after the data had been normalized to account for changes in laboratory testing procedures that occurred during this time period. Future studies need be conducted to ascertain whether the observed increase has had any effect on the incidence of crashes, serious injuries and/or traffic fatalities.

Introduction

Washington State Initiative Measure No. 502 (Initiative-502) was a public initiative that appeared on the general ballot on 6 November 2012. It defined and legalized small amounts of marijuana and marijuana-infused products for those aged 21 years and older (1). The legal amounts allowable are any combination of the following: 1 ounce of useable marijuana, 16 ounces of marijuana-infused product in solid form and 72 ounces of marijuana-infused product in liquid form (2). The initiative also sought to license and regulate the production, distribution and sale of marijuana. Possession or use by anyone under the age of 21 years, the possession of larger amounts than those allowed and the unlicensed and unregulated production, distribution or sale of marijuana all remain illegal. Statewide impaired driving laws were also amended to include a *per se* level for delta^9-tetrahydrocannabinol (THC) of 5 ng/mL in whole blood for those aged 21 years and older, while a zero tolerance was set for drivers under the age of 21 years (3, 4). Suspected impaired drivers could also be charged under the state's 'affected by' laws if it can be proven that the subject was under the influence of, or affected by, marijuana regardless of the THC concentration (3).

Initiative-502 was approved by popular vote and came into effect on 6 December 2012. The possession and use portion of the bill and the *per se* level for THC started immediately, while the licensing and regulation portion had an effective date of 6 December 2013; however, as of the time of writing, the first license to grow legal marijuana had only just been granted and the general sale of marijuana to the public via state licensed facilities is expected sometime in the future.

This study aimed at evaluating the effect, if any, that legalization of marijuana had on the prevalence of marijuana in the state's suspected impaired driving population. The demographics, frequency of both THC and 11-nor-9-carboxy-THC (carboxy-THC), actual THC blood concentrations detected and the results of concomitant alcohol and drug use in suspected impaired driving cases pre- and post-legalization are presented.

Materials and methods

Inclusion criteria for case selection

Blood toxicology results from all suspected impaired driving cases submitted by law enforcement officers from Washington State were included, between the years 2009 and 2012 (representing the 4 years prior to marijuana legalization) and for the year 2013 (the year following marijuana legalization).

Analytical testing

Blood samples are received by the Toxicology Laboratory Division of the Washington State Patrol for testing in suspected driving under the influence (DUI) and drug recognition expert (DRE) cases. All samples are tested for volatiles using headspace gas chromatography with flame ionization detection. Presumptive drug screens are performed by an enzyme multiplied immunoassay technique (EMIT, Siemens Diagnostic) for the following drug class(es): amphetamines (cutoff concentration 200 ng/mL), barbiturates (100 ng/mL), benzodiazepines (100 ng/mL), cannabinoids (10 ng/mL), cocaine metabolite (100 ng/mL), methadone (100 ng/mL), opiates (20 ng/mL), phencyclidine (10 ng/mL), propoxyphene (100 ng/mL) and tricyclic antidepressants (100 ng/mL). Based on these results and case circumstances, further confirmation testing may be performed using gas chromatography–electron impact mass spectrometry (GC–EIMS), liquid chromatography–mass spectrometry or liquid chromatography–tandem mass spectrometry.

The procedure for cannabinoid confirmation from 2009 to 2012 was a liquid–liquid extraction. Briefly, 2 mL of blood was precipitated with 5 mL of acetonitrile. The supernatant was dried down under nitrogen gas until 1 mL remained. To this, 2 mL of saturated monobasic potassium phosphate and 8 mL of

†Presented at the 2014 American Academy of Forensic Sciences annual scientific meeting, Seattle, WA.

chloroform were added. The sample was rotated for 15 min and then centrifuged at 2,000 rpm (G force 1,190 g) for 5 min. The supernatant was transferred and evaporated to dryness at 50°C. To the residue was added 40 μL of ethyl acetate and 40 μL of BSTFA + 1% TMCS (*N*, *O*-bis-trimethylsilyltrifluoroacetamide with 1% trimethylchlorosilane). After vortexing, the samples were derivatized at 70°C for 20 min. The extract was analyzed using GC–EIMS in the selected ion monitoring (SIM) mode. The internal standards used were THC-d3 and carboxy-THC-d9. Linear ranges were 1–50 ng/mL for THC and 5–200 ng/mL for carboxy-THC, with the lowest number being the reporting limit.

In 2013, a more reliable analytical method went into effect. Two milliliters of sample were precipitated with 3 mL of acetonitrile. After centrifugation at 3,500 rpm (3,640 g) for 10 min, the organic layer was transferred to a new tube, and 2 mL of 0.2 N NaOH and 4 mL of an extraction solvent consisting of hexanes : ethyl acetate (9 : 1) were added. The samples were rotated for 10 min and then centrifuged at 2,000 rpm (1,190 g) for 5 min. The organic layer (THC fraction) was transferred to new tubes and evaporated to dryness at 40°C. The aqueous layer (carboxy-THC fraction) was preserved, and 2 mL of 1 N HCl and 4 mL of extraction solvent were added. After rotation for 30 min, the tubes were centrifuged at 2,000 rpm (1,190 g) for 5 min. The organic layer was transferred and then evaporated to dryness at 40°C. The residue from both fractions was reconstituted separately with 25 μL of ethyl acetate and 25 μL of BSTFA + 1% TMCS. The samples were derivatized at 70°C for 30 min. The extracts were analyzed using GC–EIMS in the SIM mode. The internal standards used were THC-d3 and carboxy-THC-d9. Linear ranges were 2–40 ng/mL for THC and 10–200 ng/mL for carboxy-THC, with the lowest number being the reporting limit. Interassay ($n = 18$) analytical bias was 90.1–93.6% for THC and 86.8–99.2% for carboxy-THC; and interassay imprecision was 6.7–11% for THC and 3.8–7.2% for carboxy-THC.

For both methods, when quantitative results were above the linear range, the blood specimen was reanalyzed as a dilution using negative matrix.

Calculations and normalization of data

Percentages were rounded to whole numbers or to one decimal place using normal rules of rounding. Normalization of the data was done by (i) removing those cases in 2009–2012 that were positive for THC with concentrations of <2 ng/mL and carboxy-THC of <10 ng/mL, in order to match the reporting limits used in 2013 and (ii) removing 25% of positive THC and carboxy-THC cases, which additionally had an alcohol concentration of >0.10 g/100 mL, from the 2013 dataset in order to estimate the number of cases that may not have been tested for marijuana by EMIT in previous years (see 'Discussion' for details).

Statistical calculations were performed with GraphPad Prism 6 for Windows (GraphPad Software, La Jolla, CA). *P*-values of ≤0.05 were considered significant.

Results

A total of 25,719 cases from Washington State were submitted to the laboratory on suspicion of impaired driving over the course of the 5-year study period.

Table I
Demographics of Driving Subjects Testing Positive for Marijuana (THC and/or Carboxy-THC)

Year	Percent male	Age, range (years)	Age, median (years)
2009	80	14–76	25
2010	78	15–74	25
2011	81	14–70	25
2012	77	16–85	25
2013	79	14–78	26

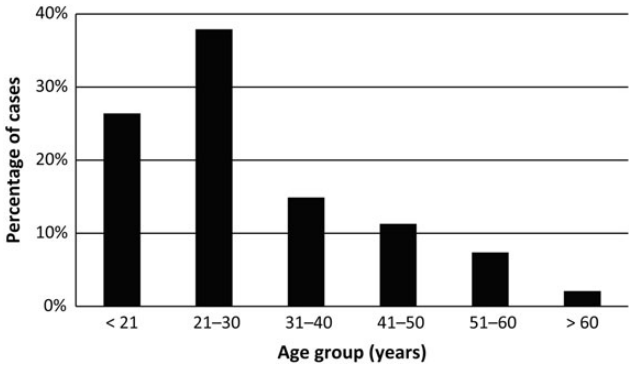

Figure 1. Distribution of age ranges for driving cases positive for marijuana (THC and/or carboxy-THC), 2009–2013 combined.

The demographics of the subjects testing positive for marijuana (THC and/or carboxy-THC) are shown in Table I, while the distribution of age ranges is shown in Figure 1. The gender and age (range and median) of subjects testing positive for marijuana were consistent across all years, with one-quarter of all positive marijuana driving cases being under the age of 21 years.

The prevalence of THC and carboxy-THC in the 25,719 driving cases is shown in Table II, with both the raw number and the percentage of total cases provided for each of the 5 years. The number of suspected impaired driving cases submitted to the laboratory for testing increases slightly every year, starting from 4,809 cases in 2009 and ending with 5,468 cases in 2013. Within this population, the percentage of cases testing positive for THC and carboxy-THC were relatively consistent for the 4 years prior to marijuana legalization (2009–2012), with an average yearly percentage of 19.1 and 27.9% testing positive for THC and carboxy-THC, respectively. In the year following legalization (2013), the percentage of cases testing positive increased to 24.9% for THC and 40.0% for carboxy-THC. This represents a percentage point increase of 5.8 and 12.1% over the previous time period for THC and carboxy-THC, respectively.

A chi-square test of independence was performed to examine the relationship between prevalence of marijuana and legislative changes. The relation between these variables was significant for both THC (χ^2 (1, $N = 5{,}468$) = 119.72) and carboxy-THC (χ^2 (1, $N = 5{,}468$) = 397.15). Marijuana prevalence increased post-legislation compared with pooled prevalence pre-legislation.

In an attempt to account for the effect of any procedural changes that occurred within the study period, the data were normalized and the results are shown in Table III. In 2009–2012, all THC results <2 ng/mL and carboxy-THC results <10 ng/mL were removed; and 25% of marijuana positive cases additionally testing positive for ≥0.10 g/100 mL alcohol

Table II
Prevalence of Carboxy-THC and THC in Blood from Suspected Impaired Driving Cases in Washington State: Raw Data

Year	Total number of impaired driving cases received for testing	Number of cases positive for carboxy-THC	Percentage of total cases positive for carboxy-THC	Number of cases positive for THC	Percentage of total cases positive for THC
2009	4,809	1,267	26.3	877	18.2
2010	5,012	1,413	28.2	974	19.4
2011	5,132	1,460	28.4	1,036	20.2
2012	5,298	1,515	28.6	988	18.6
2013	5,468	2,187*	40.0	1,362*	24.9

*$P < 0.05$.

Table III
Prevalence of Carboxy-THC and THC in Blood from Suspected Impaired Driving Cases in Washington State: Normalized Data

Year	Total number of impaired driving cases received for testing	Number of cases positive for carboxy-THC	Percentage of total cases positive for carboxy-THC	Number of cases positive for THC	Percentage of total cases positive for THC
2009	4,809	1,135	23.6	813	16.9
2010	5,012	1,243	24.8	869	17.3
2011	5,132	1,296	25.3	933	18.2
2012	5,298	1,390	26.2	970	18.3
2013	5,468	2,067*	37.8	1,302*	23.8

*$P < 0.05$.

were removed from the 2013 dataset (see 'Discussion' for details).

After normalizing the data, the overall percentages of suspected impaired driving cases testing positive for either THC and/or carboxy-THC decreased slightly for all years. Again, the percentage of cases testing positive for THC and carboxy-THC were relatively consistent for the 4 years prior to legalization, with an average of 17.7 and 25.0% testing positive for THC and carboxy-THC, respectively. In the year following legalization, the percentage of cases testing positive increased to 23.8% for THC and 37.8% for carboxy-THC. This represents a percentage point increase of 6.1 and 12.8% over the previous time period for THC and carboxy-THC, respectively. Significance was still observed using the normalized data (THC X2 = 140.03, carboxy-THC X2 = 477.93).

The actual blood THC concentrations were measured in cases testing positive for this compound, and the results are summarized in Table IV. Further, the distribution of both THC and carboxy-THC concentrations is shown in Figure 2. Normalized data were used for years 2009–2012 to provide for a more direct comparison of concentrations between years; including THC results <2 ng/mL would result in a lower average and median value for these years. The average yearly THC concentration ranged from 6.9 to 8.1 ng/mL and the median yearly THC concentration ranged from 5.2 to 6.3 ng/mL. Although there did not appear to be any consistency from 1 year to the next, a one-way analysis of variance showed that there was a significant difference in the average yearly THC concentrations, $F(4, 4{,}938) = 4.91$, $P < 0.05$. *Post hoc* analyses using Tukey's *post hoc* criterion for significance indicated that the THC concentration in 2012

Table IV
Summary of THC Blood Concentrations from Suspected Impaired Driving Cases, Including the Percentage of Cases with Concentrations ≥5 ng/mL *Per Se* Level

Year	Number of driving cases positive for THC	THC concentration range (ng/mL)	Average THC concentration (ng/mL)	Median THC concentration (ng/mL)	Number and percentage (%) of THC cases ≥5 ng/mL
2009	813	2–73	7.6	5.8	470 (58%)
2010	863[a]	2–58	7.2*	5.3	460 (53%)
2011	933	2–58	6.9*	5.3	506 (54%)
2012	970	2–90	8.1	6.3	610 (63%)
2013	1,362	2–77	7.2*	5.2	720 (53%)

Normalized data used for 2009–2012.
[a]Six cases in 2010 did not have a quantitative value of THC reported.
*$P < 0.05$ compared with 2012.

($M = 8.0$, SD = 7.0) was significantly different compared with 2010 ($M = 7.2$, SD = 6.2), 2011 (M = 6.9, SD = 5.2) and 2013 (M = 7.2, SD = 6.5). Overall, an average of 56% of cases were at or >5 ng/mL over the 5-year period, with individual year percentages ranging from 53 to 63%.

In 2013, there was an increase in the combined use of marijuana and either alcohol and/or drugs, with 60% of marijuana cases testing positive for another substance compared with 51–54% in the previous 4 years. A chi-square test of independence was performed to determine if the combined use of marijuana and either alcohol and/or drugs increased in 2013 compared with the previous 4 years. The relation between these variables was significant, χ^2 (1, $N = 2{,}188$) = 63.27, $P < 0.05$. Table V shows the most common drugs, including alcohol, detected in the marijuana driving cases. The majority of these polydrug cases had only one other substance detected in addition to marijuana, with the most frequently detected other substance being alcohol. Relatively few cases had more than two other drugs present (<15% each year). For those marijuana positive drivers under the age of 21 years, an average of only 25% had any other substances present, including alcohol that was detected in 10–15% of drivers in this age group.

There was an increase in the prevalence of alcohol in the marijuana positive driving cases in 2013 compared with the previous 4 years. The frequency of alcohol increased from 18 to 19% in 2009–2013 to 34% of cases in 2013. The distribution of alcohol concentrations, after 25% of high alcohol cases had been randomly removed, is summarized in Figure 3. Methamphetamine was the next most frequently detected substance, with 9–13% of cases testing positive. Alprazolam was detected in 5–7% of cases, oxycodone in 4–7%, diazepam in 3–6% and methadone and morphine in <5% of cases. All other illicit, recreational and prescription drugs were found less frequently.

Discussion

In 2012, it was estimated that 5.4 million persons in the USA aged 12 or older used marijuana on a daily or almost daily basis in the past 12 months, which was an increase from the 3.1 million daily or almost daily marijuana users in 2006 (5). In a 2007 National Roadside Survey of Alcohol and Drug Use by Drivers, the most frequently encountered single drug in oral fluid in both daytime and nighttime drivers was THC (6). THC was detected in oral

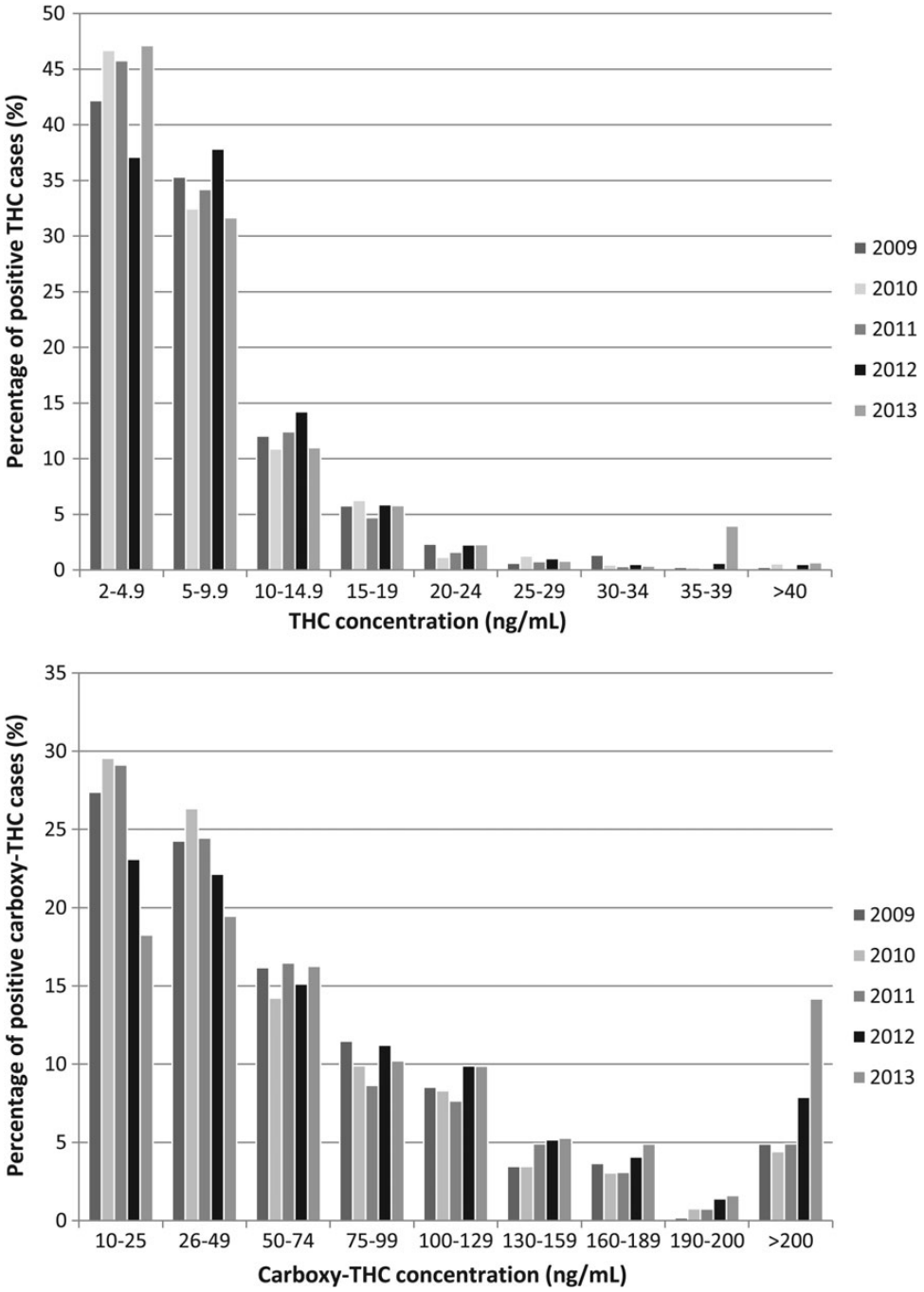

Figure 2. Distribution of THC and carboxy-THC concentrations in marijuana positive driving cases, normalized data 2009–2013.

fluid in 4.46% of daytime drivers and 7.66% of nighttime drivers. The results from nighttime drivers who provided oral fluid and/or blood indicated that 8.65% of drivers were positive for THC or its metabolites. It was further determined that drivers aged 34 or younger were more likely to test positive for THC than drivers in other age groups; and among these drivers, those aged 16–20 years had the highest THC positives (15.2%).

When it comes to drugs detected in suspected impaired driving cases, injured drivers and traffic-related fatalities in the USA and other countries, marijuana has long been one of the most frequently detected non-alcohol drugs (7–13). Because marijuana is so widely used and frequently detected in driving-related cases (fatalities and non-fatalities), it is important to monitor how changing legislation may affect the prevalence of this drug in the general driving population.

All blood samples from suspected impaired drivers in Washington state are submitted to the Washington State Patrol's Toxicology Laboratory for alcohol and drug testing; hence, the results presented here reflect statewide data. An increase in both THC and carboxy-THC was observed within the

total DUI and DRE cases submitted to the laboratory in 2013. In this same overall population, a similar increase was not observed for alcohol or the majority of other drugs over the same 5-year period, despite all cases in 2013 being screened for drugs by immunoassay and/or specific confirmatory techniques (Supplementary data I). There was a slight but significant increase observed in the prevalence of methamphetamine, morphine, hydrocodone, cocaine and hydromorphone in 2013; however, we believe that this increase is accounted for by internal laboratory changes, such as an increase in testing for drugs of abuse and an improved sensitivity for our confirmatory opiate assay, and not because of any change in the drug's prevalence of use within the population studied.

Because of several procedural changes occurring during the 5-year study period, an effort was made to normalize the data to better compare the results from each year. Where a change had occurred in the reporting limit, the data were reanalyzed to only include those results from each year within the same reporting levels.

Prior to 2013, the laboratory did not routinely conduct an immunoassay screen for drugs in suspected impaired driving cases where the blood alcohol concentration was >0.10 g/100 mL. There were often exceptions to this including vehicular homicide and/or assault cases, if drug(s) were specifically mentioned or requested, if circumstances strongly indicated drug use and/or DRE cases. In 2013, all suspected impaired driving cases were screened for both alcohol and commonly used drugs. To normalize this portion of the data, we needed a way to estimate the effect this additional testing might have.

A previous research project within the laboratory was conducted where 548 suspected impaired driving cases with alcohol concentrations >0.10 g/100 mL that had been previously untested for common drugs of abuse by EMIT were retrospectively retested for drugs (Supplementary data II). It was found that 60% of these cases were negative for common drugs of abuse; cannabinoids were presumptive positive in 22% of cases; benzodiazepines in 7%; opiates in 6%; cocaine metabolites in 3%; barbiturates and methadone in 1% of cases each and amphetamines, tricyclic antidepressants, propoxyphene and phencyclidine in none of the cases.

Because this research project showed that 22% of previously untested cases may have been positive for marijuana, it was decided to randomly remove a similar percentage (25%) of those cases in the 2013 dataset that were positive for both marijuana and ≥ 0.10 g/100 mL alcohol. The cases were removed to account for the cases in 2009–2012 that may have been presumptive positive for marijuana but were missed due to previous testing procedures. We believed that the removal of 25% was a conservative approach since, based on years of experience testing blood by EMIT, not all the presumptive positive results would have confirmed positive for carboxy-THC, and even less would have confirmed positive for THC.

Overall, it was found that the increase observed for both THC and carboxy-THC remained after the data were normalized.

In addition to the active THC, carboxy-THC was also tracked in the current study as a potential marker for overall marijuana use in the driving population, regardless of the recency of use. Moreover, many factors can affect the THC concentration in blood, potentially rendering the case as non-THC positive. The reporting limit certainly affects whether a case is classified as THC positive. The stability of THC in biological specimens prior to receipt at the laboratory and/or stored under normal laboratory conditions can be another factor, with THC concentrations potentially decreasing over time (14, 15). Subsequently, any lengthy delay by the laboratory in testing (e.g., months)

Table V
Prevalence of Alcohol and Other Drugs in the Positive Marijuana Driving Cases (THC and/or Carboxy-THC)

Percentage of marijuana cases positive for the following	2009 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)
Negative for alcohol and other drugs	48	46	50	49	40
Positive for alcohol and/or other drugs	52	54	50	51	60*
Alcohol	19	18	18	19	34
Methamphetamine	9	13	11	13	12
Alprazolam	7	6	6	5	5
Oxycodone	7	6	4	4	4
Diazepam	6	5	5	4	3
Methadone	5	5	4	4	3

*$P < 0.05$.

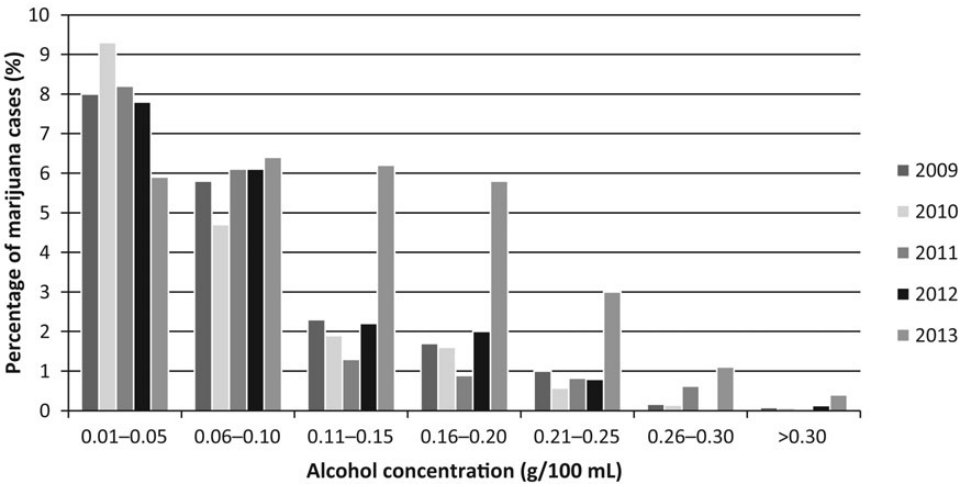

Figure 3. The distribution of alcohol concentrations in marijuana positive driving cases (THC and/or carboxy-THC), normalized data 2009–2013.

could result in decreased THC concentrations. Over the course of this study period (2009–2013), alcohol and drug testing (including THC confirmation) were typically completed within 30 days of receipt.

Because THC rapidly metabolizes in the body, any delay in the time taken to collect a blood specimen after the initial police stop could decrease the concentration subsequently detected. For example, it may make a difference if a DRE officer takes a blood sample at the start of the DRE evaluation as opposed to after completing all the steps. The recent Missouri v. McNeely Supreme Court decision (17 April 2013) led to statutory changes in Washington law and law enforcement officers in Washington State must now generally obtain a warrant prior to collecting a non-consensual blood sample; subsequently, it is potentially taking longer for police to obtain a blood specimen, which again may result in a decreased THC concentration seen.

Table V shows the percent of marijuana positive drivers additionally testing positive for alcohol or other drugs. Drivers testing positive for both alcohol and marijuana held steady at 18–19% in 2009–2012, then increased dramatically to 34% in 2013. Some of this increase can be attributed to the fact that all suspected impaired driving cases are now subject to an immunoassay drug screen regardless of the driver's alcohol concentration, and this can be seen in Figure 2 where larger increases in percentages were seen with alcohol concentrations of >0.10 g/100 mL.

Overall, this study demonstrated an increase in the prevalence of marijuana use in Washington State's suspected impaired driving population since the passage of Iniative-502 in December 2012.

Future research

While the possession and private use of marijuana is now legal in Washington State, at the time of writing it is not legally available to the public via state run licensed venues. The prevalence of marijuana in the suspected impaired driving population will continue to be tracked to determine if the future increase in availability of marijuana to the general public has any additional effect.

It is important to note that the reason for the initial police stop and/or the circumstances surrounding the arrest, including whether or not the drivers were involved in a collision, was not evaluated in this study. As a consequence, it is unknown whether the observed increase in marijuana use in the suspected impaired driving cases corresponded to any increase in collisions, serious injuries or traffic-related fatalities. This will be a focus of further research. Another area to be considered is whether the use of 0.2 N NaOH in the 2013 method converted any carboxy-THC-glucuronide to free carboxy-THC (14), and if so, whether this had a small influence on the overall prevalence of carboxy-THC cases detected in 2013. Finally, the time taken to collect the blood specimen, from when the driving took place, will be determined to ascertain how much of an effect a delay in collecting blood potentially had on the resulting THC concentrations detected.

Supplementary Data

Supplementary data are available at *Analytical Toxicology Journal* online.

Acknowledgments

The authors gratefully acknowledge the dedication and contribution of the forensic scientists in the Toxicology Laboratory Division, Washington State Patrol, without whom this research could not have been completed so timely. Appreciation also goes to forensic scientist Justin Knoy for his 2008 EMIT research project.

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