Analysis of Δ9-tetrahydrocannabinol Driving Under the Influence of Drugs Cases in Colorado from January 2011 to February 2014

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Driving under the influence (DUI) and DUI drugs (DUID) law enforcement (LE) cases (n = 12,082) where whole blood samples were submitted to ChemaTox Laboratory, Inc. in Boulder, CO, for testing were examined. Of these 12,082 cases, there were 4,235 cannabinoid screens (CS) requested. Samples that yielded a positive CS (n = 2,621) were further analyzed. A total of 1,848 samples were confirmed for Δ9-tetrahydrocannabinol (THC) after a positive CS. Due to a decrease in the confirmation limit of detection (LOD) for THC from 2 to 1 ng/mL, samples that were confirmed for THC and quantitated below 2 ng/mL (n = 250) were considered negative. After this normalization, there were 1,598 samples that were confirmed positive for THC and included in the analysis. The percentage of LE cases with requests for CS for all years was 35%, increasing from 28% in 2011 to 37% in 2013. The positivity rate of CS overall was 62% (range: 59–68% by year) with no significant change over the time frame examined. The percentage of positive CS in which THC was confirmed positive at or above 2 ng/mL (n = 1,598) increased significantly from 28% in 2011 to 65% in 2013. The mean and median THC concentrations were 8.1 and 6.3 ng/mL, respectively (range: 2–192 ng/mL, n = 1,367). The data presented illustrate a statistically significant increase in CS that result in positive THC confirmations. Although the specific cause of this increase is not known at this time, possible ties to ongoing developments in Colorado’s marijuana legislation merit further analysis.

Introduction

Marijuana is the most commonly used illicit drug in the USA (1). According to the 2012 National Survey on Drug Use and Health, 18.9 million individuals admitted having used marijuana in the month prior to the survey. Between 2007 and 2012, the rate of marijuana use increased from 5.8 to 7.3%, and the number of marijuana users increased from 14.5 to 18.0 million (1). Both the use of marijuana and public support for its legalization have recently undergone significant increases in the USA. According to a 2013 Gallup poll, a clear majority of Americans (58%) believe that marijuana should be legalized (2). This attitude is reflected in the recent legalization of recreational marijuana in the states of Colorado and Washington. These unprecedented policy changes spur awareness of the potential for individuals to drive under the influence of marijuana.

Δ9-tetrahydrocannabinol (THC) is the primary pharmacologically active component of marijuana and displays a complex pharmacokinetic profile (3, 4). Smoking is the most common route of marijuana administration as it provides rapid delivery of THC to the brain, quickly producing the desired effects of the drug. Peak effects of smoking are generally noted 20–30 min after use, with blood concentrations decreasing to low levels after 3 h and to baseline after 4 h in most users (3, 4). THC is metabolized to the active metabolite 11-hydroxy-tetrahydrocannabinol (11-OH–THC) and to the inactive metabolite 11-nor-9-carboxy-tetrahydrocannabinol (THC–COOH) (3–5). Based on the pharmacokinetic profile of THC, in particular its rapid metabolism to detectable metabolites such as THC–COOH, detection of THC in blood is essential to determine whether a subject is under the influence of, and potentially impaired by, marijuana. This underscores the imperative nature of timely collection of blood samples during driving under the influence of drugs (DUID) investigations.

THC is known to impair driving (6–10). THC impairs cognition, psychomotor function, and driving performance in a dose-related manner. Highly automated driving tasks, such as road tracking control, are the most affected by THC impairment (6, 7). THC has also been shown to impair performance on standardized field sobriety tests (SFSTs) (8). Slight driving impairment has been seen at THC serum concentrations between 2 and 5 ng/mL, and impairment becomes most notable at THC serum concentrations between 5 and 10 ng/mL (9). THC serum concentrations are greater than those quantitated in whole blood. The typical conversion factor between THC concentrations measured in whole blood versus serum is ~2, although this ratio may vary extensively (10, 11).

The state of Colorado is currently under scrutiny as the subject of what is effectively an ongoing experiment in progressive marijuana policy. Use of medical marijuana (MMJ) has been legal in the state of Colorado since 2000. Between 2000 and 2009, the number of MMJ applicants in the state of Colorado was ~10,000 (12). In order to attempt to clarify the federal role in the context of evolving state marijuana legislature, the ‘Ogden memo,’ released on 19 October 2009, stated that ‘prosecution of individuals . . . or those caregivers in clear and unambiguous compliance with existing state law who provide such individuals with marijuana . . . is unlikely to be an efficient use of limited federal resources’ (13). As witnessed in a number of states, the Ogden memo has proved to be only a guideline, not a guarantee of nonprosecution at the federal level. Between 2009 and 2010, the number of MMJ applicants in Colorado increased from ~10,000 to ~100,000 (12). Currently, more than 250,000 applications have been submitted, and there are over 113,000 active MMJ cardholders in Colorado (12). On 12 November 2012, the passing of Amendment 64 legalized private consumption of cannabis in Colorado; it was ratified in December 2012 (14). On 28 May 2013, a whole blood THC concentration of 5 ng/mL was signed into law as an indicator of ‘permissible inference’ that a defendant was under the influence of THC to an impairing degree at the time of sample collection (15). Most recently, on 1 January 2014, recreational marijuana retail stores opened to the public (14).

ChemaTox Laboratory, Inc. (ChemaTox) is a private laboratory that performs toxicological testing on whole blood and other...
bodily fluids collected by numerous \((n > 160)\) Colorado law enforcement (LE) agencies in the course of suspected DUI of alcohol and drug investigations. In this study, the results of testing of whole blood samples collected from drivers in suspected DUI/D cases in Colorado during the period of January 2011 to February 2014 were analyzed. The results obtained during this time frame were evaluated in order to determine the total number/rate of LE samples submitted, the number of requests for drug testing versus for alcohol testing (DUID versus DUI), the number of drug requests specifically for cannabinoid screens (CS), the number of positive results for CS requests, and the number of positive CS requests that were confirmed positive for THC. A reorganization of available toxicological testing laboratories in Colorado during this time period led to a large sample influx. In order to normalize for this occurrence, the above-listed criteria were also analyzed for a single Denver metropolitan area LE agency for which ChemaTox performed exclusive testing throughout the entirety of the time frame examined. Limited data from January and February of 2014 were available at the time of the study. The results from January and February of all four years were analyzed in addition to the full year data to allow for better comparison.

**Methods**

**Samples and subjects**

DUI and DUID LE cases \((n = 12,082)\) where whole blood samples were submitted to ChemaTox for testing were examined. Limited information is submitted with the samples and includes, but is not limited to, agency name, date and time of the incident, incident and date of the blood draw, offense, testing requested, medications taken, and chain of custody information. The officer occasionally provides other case information, including limited demographic or narrative case information. Drug Recognition Expert (DRE) and Advanced Roadside Impaired Driving Enforcement (ARIDE) information for cases is generally not provided and is not readily accessible to the authors. Of these 12,082 cases, there were 4,235 CS requested. Samples were screened upon receipt and stored at \(<8^\circ C\) when not being tested. THC confirmation testing was performed between 7 and 60 days from receipt in almost all cases. Samples that yielded a positive CS \((n = 2,621)\) were further analyzed with respect to the following: age and gender of the subject, other positive drugs (including alcohol,) THC concentration and time elapsed between time of stop (TOS), and time of draw (TOD). Available cases \((n = 13)\) in which THC was originally confirmed qualitatively \(>20\) ng/mL were reprocessed in order to obtain exact quantitation. Quantitative analysis had not originally been performed on these samples for administrative reasons that were based on the lack of relevance of a precise concentration of THC above a substantially impairing concentration with respect to LE cases. The remaining 44 samples that were originally reported as qualitatively \(>20\) ng/mL were examined and their approximate concentrations based on the original curves were used solely in establishing the distribution of samples in the \(>20\) ng/mL range. These approximate values were not used in any calculations.

A subset of samples \((n = 661)\) from a Denver Metro agency from which whole blood samples were received consistently through the full 38-month period was examined. Due to the large sample influx received in 2013 and 2014, this subset of data was analyzed to assess the possible influence of the change in demographics of the samples received on the overall data analysis.

Cases for review were selected based on the availability of police reports in cases where the subject performed voluntary roadside maneuvers. Five cases in which THC was confirmed positive \(\geq 2\) ng/mL were selected due to the range of THC concentrations both above and below the \(5\) ng/mL per se DUI—THC limit in Colorado, as well as the fact that some drivers were contacted based on bad driving, while others were contacted based on vehicular malfunctions (e.g., broken taillight).

**Analysis of case samples**

Whole blood samples are submitted to ChemaTox from some Colorado LE agencies in order to be tested for alcohol and other drugs in suspected DUI or DUID investigations. Drug testing is based on the request of the arresting officer; additional testing based on case analysis may be requested via arresting officers or by the office of the District Attorney. The scope of toxicological testing available for request includes alcohol and \(~50\) basic and acidic drugs. Drug screens are performed using enzyme-linked immunosorbent assay (ELISA), if available, and confirmed by gas chromatography–mass spectrometry (GC–MS) or liquid chromatography–tandem mass spectrometry (LC–MS–MS). Available ELISA screens may be requested in the form of our standard 5-, 7- or 11-panels, which are based on the most frequently positive drug classes observed in LE cases.

All LE samples received by ChemaTox are analyzed for the presence of ethyl alcohol. The laboratory utilizes headspace gas chromatography with flame ionization detection (HS–GC–FID) in order to determine the concentration of ethyl alcohol in submitted blood samples. The ethyl alcohol limit of detection (LOD) for the samples presented in this study that were tested prior to 2014 was \(0.005\) g/100 mL; for samples tested beginning in 2014, the LOD was \(0.005\) g/100 mL.

Initial presumptive testing for cannabinoids was performed via ELISA. The CS ELISA is directed to THC–COOH, with an in-house established cutoff of \(20\) ng/mL in whole blood. The CS ELISA has an in-house verified cross-reactivity to THC of \(21\%\).

Prior to April 2013, whole blood samples that yielded a positive CS via ELISA were confirmed for the presence of THC and THC–COOH via GC–MS. Samples were prepared for GC–MS analysis using solid-phase extraction (SPE). A deuterated internal standard, THC-d3, was used for quantitation of THC. THC–COOH results confirmed positive via GC–MS were reported qualitatively as required by the administrative protocol of the lab.

As of April 2013, whole blood samples that yielded a positive CS via ELISA were confirmed for THC and THC–COOH via LC–MS–MS. Samples were prepared for LC–MS–MS analysis using an acetonitrile protein crash technique. Deuterated internal standards for THC and THC–COOH (THC-d3 and THC–COOH–d3, respectively) were used for quantitation.

In the course of this analysis, any reference to confirmation testing (i.e., ‘confirmed’) does not differentiate between confirmation performed via GC–MS and confirmation performed via LC–MS–MS. Refer to Table 1 for a comprehensive list of technique, LOD, lower limit of quantification (LLOQ) and upper limit of quantification (ULOQ), for a given analyte in a given date range. Due to the decrease in LOD for THC from 2 to \(1\) ng/mL, samples that were confirmed for THC and quantitated below \(2\) ng/mL \((n = 250)\) were considered negative. After this
normalization, there were 1,598 samples that were confirmed positive for THC and included in further analysis.

**Data analysis**

Student *t*-tests were performed assuming unequal variance and that the populations were independent. This analysis was performed for full year data for overall percentage of positive CS confirmed for THC ≥ 2 ng/mL (2012 versus 2011, 2013 versus 2012) and for the Denver Metro Agency subset. This analysis was also performed for the change in median THC concentration compared with the TOS to TOD interval.

**Results**

**Cannabinoid screening results**

The 12,082 LE cases with whole blood samples received during the 38-month period were examined. Drug testing was only performed on samples for which drug testing was requested by the submitting agency (i.e., samples where only alcohol testing was requested were not tested for cannabinoids). In addition to the full year analysis, data were also compared for January and February of each year in order to compensate for the 2-month limitation for 2014. For the full time period studied, there were 4,235 (35%) requests for CS. Of the samples screened, 2,621 (62%) were positive and sent on for confirmation testing. The total number of samples tested including the total number of requests, total CS, positive CS, and samples confirmed positive for THC are summarized in Table II. The percentage of LE cases with requests for CS for all years was 35%, increasing from 28% in 2011 to 37% in 2013. The positivity rate of CS overall was 62% (range: 59–68%) with no significant change over the time frame examined. The analysis of the January and February data was similar to the full year data, showing an increase in the number of samples with requests for CS and a steady positivity rate of the CS at ~66% overall (range: 63–68%).

**THC confirmation results**

In this study, positive CS cases were confirmed by GC–MS or LC–MS–MS. Of the cannabinoid class, only THC was quantitatively evaluated because THC–COOH was only reported qualitatively for the majority of the time frame examined. The percentage of positive CS confirmed for THC ≥ 2 ng/mL (Table II) increased from 28% in 2011 to 65% in 2013 (full year analysis) and from 34% in 2011 to 71% in 2014 (January/February analysis). The full year increase was significant for 2011–2012 and for 2012–2013 (both *P* < 0.001). These data are detailed in Table II.

The mean and median THC concentrations were 8.1 and 6.5 ng/mL, respectively (range: 2–192 ng/mL, *n* = 1,367). There were 231 samples excluded from the mean and median calculations because they were originally reported qualitatively and no quantitative results were available. Figure I illustrates the distribution of THC concentrations for the full 38-month period, including cases where the THC concentration was < 2 ng/mL. A total of 890 cases (48%) of the full 1,848 THC-positive

### Table I

Limits of Detection and Quantitation Over Time for Blood Alcohol Testing, THC and THC–COOH Confirmations

<table>
<thead>
<tr>
<th>Testing date(s)</th>
<th>Analyte</th>
<th>Technique</th>
<th>LOD</th>
<th>LLOQ</th>
<th>ULOQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 2013</td>
<td>Ethyl alcohol</td>
<td>HS-GC–FID</td>
<td>0.003 g/100 mL</td>
<td>0.003 g/100 mL</td>
<td>0.500 g/100 mL</td>
</tr>
<tr>
<td>January 2014 and later</td>
<td>Ethyl alcohol</td>
<td>HS-GC–FID</td>
<td>0.005 g/100 mL</td>
<td>0.010 g/100 mL</td>
<td>0.500 g/100 mL</td>
</tr>
<tr>
<td>Confirmations Testing date(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior to April 2013</td>
<td>THC</td>
<td>GC–MS</td>
<td>2 ng/mL</td>
<td>5 ng/mL</td>
<td>30 ng/mL</td>
</tr>
<tr>
<td>April–December 2013</td>
<td>THC</td>
<td>LC–MS–MS</td>
<td>1 ng/mL</td>
<td>1 ng/mL</td>
<td>20 ng/mL</td>
</tr>
<tr>
<td>January 2014 and later</td>
<td>THC</td>
<td>LC–MS–MS</td>
<td>1 ng/mL</td>
<td>1 ng/mL</td>
<td>50 ng/mL</td>
</tr>
<tr>
<td>Prior to April 2013</td>
<td>THC–COOH</td>
<td>GC–MS</td>
<td>10 ng/mL</td>
<td>Reported qualitatively</td>
<td>–</td>
</tr>
<tr>
<td>April–December 2013</td>
<td>THC–COOH</td>
<td>LC–MS–MS</td>
<td>5 ng/mL</td>
<td>10 ng/mL</td>
<td>200 ng/mL</td>
</tr>
<tr>
<td>January 2014 and later</td>
<td>THC–COOH</td>
<td>LC–MS–MS</td>
<td>5 ng/mL</td>
<td>10 ng/mL</td>
<td>300 ng/mL</td>
</tr>
</tbody>
</table>

**Table II**

Total Number of Samples by Category and Year with Percentage of Samples Screened, Positive Screens, and Positive THC Confirmations in Whole Blood Samples

<table>
<thead>
<tr>
<th>Time period</th>
<th>LE requests</th>
<th>CS</th>
<th>Positive screens</th>
<th>Confirmed THC</th>
<th>% LE with CS</th>
<th>% CS positive</th>
<th>% CS with confirmed positive THC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1,595</td>
<td>453</td>
<td>283</td>
<td>79</td>
<td>28</td>
<td>62</td>
<td>28</td>
</tr>
<tr>
<td>2012</td>
<td>1,691</td>
<td>485</td>
<td>324</td>
<td>190</td>
<td>29</td>
<td>67</td>
<td>59</td>
</tr>
<tr>
<td>2013</td>
<td>7,420</td>
<td>2,774</td>
<td>1,659</td>
<td>1,076</td>
<td>37</td>
<td>59</td>
<td>65</td>
</tr>
<tr>
<td>2014b</td>
<td>1,376</td>
<td>523</td>
<td>355</td>
<td>253</td>
<td>38</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>2011–2014 total</td>
<td>12,082</td>
<td>4,235</td>
<td>2,621</td>
<td>1,598</td>
<td>35</td>
<td>62</td>
<td>61</td>
</tr>
<tr>
<td>J &amp; F 2011</td>
<td>223</td>
<td>56</td>
<td>35</td>
<td>12</td>
<td>25</td>
<td>63</td>
<td>34</td>
</tr>
<tr>
<td>J &amp; F 2012</td>
<td>220</td>
<td>57</td>
<td>37</td>
<td>22</td>
<td>26</td>
<td>65</td>
<td>59</td>
</tr>
<tr>
<td>J &amp; F 2013</td>
<td>379</td>
<td>135</td>
<td>85</td>
<td>61</td>
<td>36</td>
<td>63</td>
<td>72</td>
</tr>
<tr>
<td>J &amp; F 2014</td>
<td>1,376</td>
<td>523</td>
<td>355</td>
<td>253</td>
<td>38</td>
<td>68</td>
<td>71</td>
</tr>
<tr>
<td>J &amp; F 2011–2014 total</td>
<td>2,198</td>
<td>771</td>
<td>512</td>
<td>348</td>
<td>35</td>
<td>66</td>
<td>68</td>
</tr>
</tbody>
</table>

*The confirmed THC results are the adjusted sample numbers where all samples below 2 ng/mL THC were excluded. Percent of LE samples that were screened for cannabinoids, the percent of samples screened that were positive and the percent of positive screens in which THC was then confirmed in the sample are also listed.

*2014 only January and February data included.

CS, cannabinoid screens; LE, law enforcement; J & F, January and February.

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LOD, limit of detection; LLOQ, lower limit of quantitation; ULOQ, upper limit of quantitation.

HS-GC–FID, headspace gas chromatography with flame ionization detection; LC–MS–MS, liquid chromatography with tandem mass spectrometry; GC–MS, gas chromatography mass spectrometry; LOD, limit of detection; LLOQ, lower limit of quantitation; ULOQ, upper limit of quantitation.
cases had THC concentrations of < 5 ng/mL; 250 (13.5%) samples had concentrations < 2 ng/mL. These cases are representative only of samples that were tested after the decrease of the LOD for THC from 2 to 1 ng/mL. Of all cases that were at or above the 2 ng/mL THC, 640 (40%) were below 5 ng/mL THC and therefore below the permissible inference level in Colorado.

**Demographic and time elapsed results**

Approximately 87% of subjects from whom samples were collected were male; ~ 13% were female. The median age of male and female subjects was 24 years (range: 14–77). There were 2,323 cases that had positive CS results and sufficient case information available to determine the time elapsed between the stop and the blood draw. The median elapsed time between the TOS and TOD was 1.05 h for all cases with positive CS results. A total of 1,465 cases had THC confirmations and sufficient information available to determine the time elapsed between the TOS and TOD with a median elapsed time of 1.03 h. In the cases that were confirmed positive with a quantitative result for THC in which the elapsed time could be determined (n = 1,288), there is a significant decrease in THC concentration as elapsed time increases, as would be expected given the known metabolism of THC. The change in median THC concentration between the 0.25–0.99 h and 1–1.99 h was not significantly different. However, there was a significant change in median THC concentration between the 0.25–0.99 h and > 2-h data points and between the 1–1.99 h and the > 2-h data points (P < 0.004 and P < 0.007, respectively). Figure 2 illustrates the median THC concentrations for each time range. These data underscore the importance of acquiring blood samples as close to the time of the incident as possible in order to most accurately quantitate the approximate amount of THC in blood at the time of the incident.

**Other drugs found**

In THC-positive cases, the most common single additional drug class was alcohol (n = 612). Testing for ethyl alcohol is performed on all blood samples submitted in LE cases. Of the 1,598 THC-positive cases, 539 (34%) were screened for other
drugs in addition to alcohol. Methamphetamine ($n = 71$), cocaine ($n = 65$) and benzodiazepines ($n = 48$) were the most common single additional drugs after alcohol. There were also cases in which two ($n = 48$) or three ($n = 18$) additional impairing drugs were confirmed in the sample. A total of $511 (32\%)$ of the THC-positive samples were also positive for ethyl alcohol at $>0.050 \text{ g ethyl alcohol/100 mL}$ (range: $0.057–0.321$, median $= 0.135$), the Driving While Ability Impaired (DWAI) alcohol limit in Colorado. In addition, $101$ samples ($6\%$) were positive for alcohol at or below this DWAI limit. Figure 3 shows the proportions of THC and alcohol cases. In cases where the only drugs detected were alcohol and THC ($n = 612$), the median THC concentration was $4.6 \text{ ng/mL}$ (range: $2–58 \text{ ng/mL}$ THC in whole blood), and the median alcohol concentration was $0.119 \text{ g ethyl alcohol/100 mL}$ (range: $0.010–0.321$ g ethyl alcohol/100 mL blood).

**Denver metro area subset analysis**

For the full time period studied, there were $323 (49\%)$ requests for CS. Of the samples screened, $217 (67\%)$ were positive and then underwent confirmation testing. The total number of samples tested, including the total number of requests, CS, positive CS and samples confirmed positive for THC, are summarized in Table III. The percentage of LE cases with requests for CS for all years was $49\%$ (range: $42\%–56\%$, excluding 2014). The positivity rate of CS overall was $67\%$ (range: $59\%–74\%$, excluding 2014).

The percentage of positive CS confirmed for THC $\geq 2 \text{ ng/mL}$ ($n = 142$) increased from $39\%$ in 2011 to $79\%$ in 2013 for the full year analysis. These data are detailed in Table III. The full year increase was significant for 2011–2012 and for 2012–2013 (both $P < 0.001$). The mean and median THC concentrations were $9$ and $8 \text{ ng/mL}$, respectively (range: $2–26 \text{ ng/mL}$, $n = 142$).

<table>
<thead>
<tr>
<th>Time period</th>
<th>LE requests</th>
<th>CS positive</th>
<th>Positive screens</th>
<th>Confirmed THC</th>
<th>% CS with CS positive</th>
<th>% CS with confirmed positive THC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>192</td>
<td>108</td>
<td>64</td>
<td>25</td>
<td>56</td>
<td>59 (39)</td>
</tr>
<tr>
<td>2012</td>
<td>204</td>
<td>87</td>
<td>58</td>
<td>40</td>
<td>42</td>
<td>67 (69)</td>
</tr>
<tr>
<td>2013</td>
<td>238</td>
<td>117</td>
<td>86</td>
<td>68</td>
<td>49</td>
<td>74 (79)</td>
</tr>
<tr>
<td>2014b</td>
<td>27</td>
<td>11</td>
<td>9</td>
<td>9</td>
<td>41</td>
<td>82 (100)</td>
</tr>
<tr>
<td>2011–2014</td>
<td>661</td>
<td>323</td>
<td>217</td>
<td>142</td>
<td>49</td>
<td>67 (65)</td>
</tr>
</tbody>
</table>

The confirmed THC results are the adjusted sample numbers where all samples below $2 \text{ ng/mL}$ THC were excluded. Percent of LE samples that were screened for cannabinoids, the percent of samples screened that were positive and the percent of positive screens in which THC was then confirmed in the sample are also listed.

2014 only January and February data included.

CS, cannabinoid screens; LE, law enforcement.

### Table IV

Five selected DUID cases with THC as the only drug detected

<table>
<thead>
<tr>
<th>Case</th>
<th>THC in ng/mL</th>
<th>ΔT (h)a</th>
<th>OLSb</th>
<th>WATb</th>
<th>HGNb</th>
<th>Cause of traffic stop</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.8</td>
<td>0.7</td>
<td>4/4</td>
<td>3/8</td>
<td>0/6</td>
<td>Traffic violation</td>
<td>Eyelid tremors, difficulty balancing</td>
</tr>
<tr>
<td>2</td>
<td>4.5</td>
<td>1.9</td>
<td>2/4</td>
<td>4/8</td>
<td>0/6</td>
<td>Traffic violation</td>
<td>Eyelid tremors, slurred speech, disoriented</td>
</tr>
<tr>
<td>3</td>
<td>5.8</td>
<td>1.3</td>
<td>4/4</td>
<td>7/8</td>
<td>6/6</td>
<td>Poor driving</td>
<td>Slurred speech, disoriented</td>
</tr>
<tr>
<td>4</td>
<td>9.3</td>
<td>1.1</td>
<td>4/6</td>
<td>6/6</td>
<td>6/6</td>
<td>Traffic violation</td>
<td>Eyelid tremors, difficulty balancing</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
<td>1.4</td>
<td>2/4</td>
<td>3/8</td>
<td>2/6</td>
<td>Poor driving</td>
<td>Eyelid tremors, difficulty balancing</td>
</tr>
</tbody>
</table>

The Standard Field Sobriety Test results are summarized along with time between stop and draw, the cause of the stop and notes from the officer about the case.

Notes:

aElapsed time between stop and draw in hours.
bOne leg stand: standing for 30 s on subject’s choice leg.
Walk and turn: Nine heel-to-toe steps followed by turn and nine more heel-to-toe steps.
Horizontal gaze nystagmus: Lack of smooth pursuit, distinct nystagmus at maximum deviation, and angle of onset prior to 45°.

### Case reviews

Five cases where THC was the only drug detected after a full drug screen was performed were examined to look at the following factors: the THC concentration confirmed (range: 2.8–28 ng/mL). Standard Field Sobriety Test results, time between stop and draw (range: 0.7–1.9 h), the cause of the stop and notes from the officer about the case. These results are summarized in Table IV. Despite the fact that horizontal gaze nystagmus (HGN) is not typically associated with THC impairment, no other CNS depressants were found in the subjects’ samples.

### Discussion

Collection of DUID–THC data in states that legalize marijuana is critical to the evaluation of the potential impact of legalization on impaired driving. The progression of marijuana legalization in Colorado has been gradual, spanning >10 years. The major increase in MMJ applicants between 2009 and 2010 would have been a likely window in which DUID–THC cases might be
expected to dramatically increase. It is possible that many Colorado residents desiring to regularly use marijuana made the decision during this crucial time frame to either obtain their MMJ registration or to continue to use marijuana outside of any state regulatory system, which could explain the relatively low increase in number of applicants in subsequent years. The legalization of recreational marijuana retail locations may also cause an increase in DUID–THC cases; however, given the gradual changes in the marijuana laws, it is unlikely that any potential increase will be as substantial as the changes that may have occurred between 2009 and 2010. The data available presented do not cover the 2009–2010 timeframe, and therefore, this analysis is not possible.

Based on the case reviews presented in Table IV, the data support that the individuals from whom these samples were collected were impaired—both at relatively low and high levels of THC, and some at a level below the 5 ng/mL permissible inference limit. This is evidenced in part by these individuals’ driving behavior but more often by behavior observed by LE agents. Even when suspected DUID drivers are contacted for non-driving offenses (e.g., nonilluminated taillights), they may exhibit substantial impairment both on voluntary roadside maneuvers and/or in their ability to interact in a sober manner with LE agents. It is therefore imperative for LE agents to be able to recognize THC-impaired drivers in the course of contact that is not necessarily initiated because of obviously impaired driving. This is of particular importance in light of the fact that 40% of all cases, which were at or above the 2 ng/mL THC, were below 5 ng/mL THC (Figure 1) and therefore below the permissible inference level in Colorado.

It is possible that public opinion regarding THC intoxication and driving may be similar to traditional views regarding DUID of alcohol: a commonly cited misconception about DUID is that ‘everyone does it’ (16). This reinforces the attitude that occasionally driving while impaired, or only driving when it is perceived as absolutely necessary, is not a dangerous activity. This is reflected in attitudes toward THC impairment: many drivers not only believe that current DUI laws do not apply to marijuana use, but that they actually ‘drive better high’ (17). It is important to promote awareness of the fact that although drivers under the influence of THC may be able to compensate for some of its impairing effects through exaggeratedly cautious driving, they are not equipped to respond appropriately to unforeseen driving circumstances and still present a major danger to public safety. All of these factors indicate that public education concerning THC impairment should also be a priority.

The analysis ideally provides a baseline for comparison in order to evaluate any impact incurred by the legalization of recreational marijuana in Colorado. Given the steady rate of positive CS, we do not expect to see a large increase in the incidence of suspected DUID–THC as a direct effect of the most recent legislation due to the gradual nature of the changing legal status of marijuana in the state. An increase in positive CS cases that then have THC confirmed is more likely given current trends seen in these data. Future useful efforts may include analysis of the proportion of out-of-state drivers convicted of DUID–THC in Colorado. This may aid in examining the risks of so-called ‘pot tourism’, as well as the necessity of public education regarding THC and driving at the national level. Information regarding the role played by recreational dispensaries in DUID–THC cases could potentially be elucidated by analyzing the number of drivers who ingest THC orally versus smoking. Smoking is the primary route of administration for recreational users of THC. Oral alternatives, such as ‘brownies’, may previously have been less convenient and more expensive due to the labor involved in their production, rendering even experienced smokers relatively naive to their particular effects. This naivete would be expected to be even more pronounced in individuals who may have been previously deterred from THC use by the apparent requirement of smoking. The increased availability of edible THC products, introduced most blatantly in the form of dispensary vending machines, may lead to an increased number of THC users who opt for oral administration. The pharmacokinetics of orally ingested THC present lower peak concentrations than those observed after smoking (18). Further, after oral administration, peak concentrations of THC occur hours later (3, 18). This may suggest that users of oral THC alternatives may not feel the expected high initially and therefore continue to consume numerous oral doses. As a result, high THC concentrations due to oral administration alone or in individuals who choose to smoke and use oral administration concurrently may be seen in the blood of impaired drivers.

Quantitation of THC–COOH is now standard for samples that are confirmed after a positive CS and will be included in future analysis. Quantitation of cannabinoids other than THC and THC–COOH may also allow insight into Colorado DUID cases. In the future, ChemTox may offer detection and quantitation of 11-hydroxy-THC (11-OH–THC), cannabidiol (CBD), and cannabiol (CBN). Particularly in the competitive field of MMJ, as well as in the new recreational field, different strains containing variable concentrations of THC versus CBN or CBD may be marketed toward individuals interested in varying types of high. These compounds may also be useful markers of a timeline of use or to explain interindividual variability of level of impairment at similar THC concentrations. Analyzing the CBN, CBD, and 11-OH–THC concentrations in the blood of DUID–THC drivers may provide a more thorough and accurate understanding of these cases (19).

Conclusion
The data presented illustrate a statistically significant increase in CS that result in positive THC confirmations. Similar trends are observed both in the data for all cases examined and for the single Denver Metro agency. The cause of the increase in positive THC confirmations is unclear at this time. This increase may be due to one, a combination or all of the following: changes in public opinion of marijuana use, the legalization of recreational marijuana, the emergence of naive marijuana users given the recreational legalization, and increased vigilance and/or education on the parts of LE agents with respect to DUID–THC. Given the normalization of the data based on the change in LOD, the increase in confirmed THC-positive cases is not due to a change in testing sensitivity. The CS targets THC–COOH while the confirmation targets THC, which has a much shorter detection window than THC–COOH. THC is a better indicator of recent use and possible acute impairing effects, and the statistically significant increase in CS that result in positive THC confirmations is of particular interest.

Limitations of this study include the partial data available for 2014. Further data analysis will need to be performed when a
full year of data is available. Additionally, samples that were above the ULOQ render some of the data unusable; it was therefore not considered in calculations. Furthermore, some THC-positive samples were likely missed when no CS was requested by LE due to more apparent use of alcohol and/or other drugs. While more data will need to be collected in order to perform more conclusive analysis, it is important to recognize the relevance of the data presented to public safety for all individuals on the road.

In the face of the ongoing changes in the legal status of marijuana, data collection from Colorado and other states that have or may legalize marijuana is critical in order to better understand how legalization may affect incidence rates and aspects of DUID−THC cases. It is also essential that more case information be provided so that the 5 ng/mL permissible inference in Colorado may be better evaluated in terms of its efficacy in protecting public safety. Future studies may include a comparison between THC concentrations in whole blood and officer observations of impairment. Understanding the multiple facets that may affect DUID−THC cases is becoming increasingly important as more cases are coming into the laboratory.

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References


14. CO. Const. Art. 18, § 16.

15. Colorado Revised Statues (CRS) 42-4-1301.


