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TECHNICAL NOTE

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A Two-Year Study of Δ 9 Tetrahydrocannabinol Concentrations in Drivers; Part 2: Physiological Signs on Drug Recognition Expert (DRE) and non-DRE Examinations*,†,‡

ABSTRACT: Whole blood samples were examined for Δ^9-Tetrahydrocannabinol (THC) over 2 years in drivers suspected of driving under the influence. Part one of the study examined the link between [THC] and performance on field sobriety tests. This portion examined objective signs, eye examinations and physiological indicators; and their relationship to the presence of THC. Several objective signs were excellent indicators of the presence of THC: red eyes (94%), droopy eyelids (85.6%), affected speech (87.6%), tongue coating (96.2%), and odor of marijuana (82.4%). About 63.6% of THC positive subjects had dialted pupils (room light). THC positive subjects had either rebound dilation or hippus in 88.8% of cases. Pulse and blood pressure (BP) were evaluated to determine any correlation with [THC]. An increased pulse rate correlated well to the presence of THC (88.5%), but not [THC]. BP did not correlate to [THC] and was also a poor indicator of THC in the blood (50% high).

KEYWORDS: forensic science, marijuana, driving under the influence of drugs, Drug Recognition Expert, physiological signs, dilated pupils, rebound dilation

Driving under the influence of drugs (DUID) has become a growing issue nationwide and likewise in Orange County, California. Nationally, the amount of alcohol-related crashes has been on the decline, but drug-related crashes have increased (1,2). According to the 2013–2014 National Roadside Survey, approximately 20% of drivers are positive for one or more drugs in blood. This represents an increase from the 2007 roadside survey in which 16.3% of drivers tested positive for one or more drugs (3). In Orange County, California, nearly 5000 drivers were suspected of DUID from 1 November 2010 through 30 November 2012, which is more than double the number from the same timeframe 10 years prior.

The 2015 National Survey on Drug Use and Health reported that marijuana use in the United States has increased from 14.5 million current (past month) users aged 12 years and older in 2007 to 19.8 million in 2013. At the same time, the use of other illicit drugs has stabilized or decreased. This increase in ingestion is partially due to legalization of marijuana for recreational use in Washington, Colorado, Oregon, Alaska, and Washington DC along with the decriminalization or medical marijuana in many other states. This increase makes marijuana the most common illicit drug in America (2). These trends are likely to continue with the recent addition of California, Nevada, Maine, and Massachusetts legalizing recreational use of Marijuana in 2016. After alcohol, marijuana was the most common drug among drivers fatally injured in a Washington study where 12.7% were positive for the psychoactive Δ^9-Tetrahydrocannabinol (THC) or its inactive metabolite, 11-carboxy-THC (Carboxy-THC) (4). These statistics reflect the national shift toward the social acceptance of marijuana use which creates an increased risk of individuals operating motor vehicles while impaired.

During an investigation, the officer may conduct a series of psychophysical tests, or Standardized Field Sobriety Tests (SFSTs), to facilitate the decision for arrest. If drugs are suspected in the investigation, a DRE evaluation is often requested. The DRE evaluation is a powerful aid in determining whether an individual is under the influence of drugs and specifically which category of drug is affecting them. The program consists of twelve systematic and standardized steps that aid in determining whether an individual is impaired for the purposes of driving. Officers are trained to recognize whether the observed impairment is related to a medical condition/emergency or if the impairment is due to a certain category of drug (5). A 2-year study in Oregon showed that face-to-face interaction with the

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‡Authors all work for The Orange County Crime Laboratory testifying on driving under the influence cases, specifically in regard to marijuana, which represents a possible conflict of interest

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suspect, physical evidence and admissions made by the individual gave additional support to the opinion of impairment made by law enforcement. The recognition of individuals deemed under the influence of marijuana had an accuracy of 80.7% when the decision was solely based on suspect observation and DRE evaluation (6). The ultimate goal of the DRE program is to "help... prevent crashes, deaths and injuries caused by drug-impaired drivers (5)."

There is limited research regarding the use of marijuana and performance during a DRE evaluation. However, numerous controlled and field studies have documented a link between poor FST performance and impairment (6–11). The number of studies examining the physiological aspects, such as pupil size, blood pressure, and eye signs, of the DRE examination is less plentiful (10,11).

The initial goal of this study was to examine police reports and DRE evaluations of THC positive samples within a 2-year timeframe to determine whether there is a correlation with whole blood THC concentrations, driving pattern, and FST performance on DRE and non-DRE evaluations. The results from that portion of the study have been previously reported (12). However, there were additional data from the DRE examinations that were not previously presented due to limitations in space. Those results are presented in this addition to the original paper *A Two Year Study of Δ 9 Tetrahydrocannabinol (THC) Concentrations in Drivers; Examining Driving and Field Sobriety Test (FST) Performance*.

Methods

The Orange County Crime Laboratory (OCCL) serves 34 city law enforcement agencies, unincorporated areas, and state-patrolled roadways that comprise the County of Orange, California. In DUI cases, whole blood sample are collected by licensed phlebotomists in 25 mL glass vials containing potassium oxalate (anti-coagulant) and sodium fluoride (preservative). The OCCL receives all toxicological samples obtained for drivers arrested for suspicion of DUI/DUID in Orange County. Samples submitted with driving charges are first tested for alcohol and other volatiles. If a sample contains less than 0.08% (w/v) blood alcohol content, it is tested for drugs. Those samples were screened by enzyme-linked immunosorbant assay (ELISA) using kits from Immunalysis™ (Pomona, CA). This method is described elsewhere (12). Cannabinoid-positive samples were then confirmed by a solid phase extraction and a gas chromatograph/mass spectrometer (GCMS) selected-ion monitoring (SIM) method to detect delta-9-tetrahydrocannabinol (THC) and its inactive metabolite, 11-carboxy-tetrahydrocannabinol (Carboxy-THC). This method is described elsewhere (13). The limit of quantification (LOQ) for both THC and Carboxy-THC is 2 ng/mL, and samples containing less than this value for each drug were reported as "not detected." THC concentrations were reported in whole numbers during the period of the study. All samples included in this study also had an alkaline/neutral drug screen by extraction of drug into an organic layer and analysis using a gas chromatograph-nitrogen phosphorus (GC-NPD) detector and GCMS. This method is also described elsewhere (14,15). This additional analysis tested for other potentially psychoactive substances, including prescription and over-the-counter drugs.

From 1 November 2010 through 30 November 2012, 1204 whole blood samples contained THC alone or in combination with other drugs. Samples that contained THC during this time frame were eliminated from the study if they contained less than 8 mL of blood, which resulted in 172 samples being eliminated for insufficient volume. The volume requirement was to ensure that this study did not compromise active criminal cases which would need sufficient blood if additional testing was requested. Cases were also removed from the study if they were confirmed positive for other drugs, or if the officer suspected the presence of a drug that the OCCL does not test for, to ensure that the symptoms described in the police evaluations were due solely to the effects of marijuana ingestion. In total, 639 samples were eliminated from the study due to the presence of other drugs, eight of which were drugs OCCL does not test for (but were reported by subjects). Police reports were obtained and reviewed for the remaining 393 case samples that were determined to contain only THC. Cases were further eliminated from the data set if for any reason the entire DUI investigation was not completed due to traffic collision or hospital transport, or if the researchers determined that the suspect was not actually driving (i.e., the suspect was the passenger of the vehicle). This left a remaining 363 cases that were evaluated in this study. These remaining samples were evaluated using only the data (i.e., FST performance, DRE exam, driving behavior, tested levels), and the biographical information was not recorded. Of the 363 cases reviewed, 116 individuals (55.9%) received a subsequent evaluation by a DRE officer.

Objective Signs

The prevalence of each of the objective signs of marijuana use was tabulated for individuals testing positive for THC. Not every objective sign was mentioned in each report. As officers have different levels of training and make notations differently, it cannot be assumed that the failure to note an objective sign is the same as the sign being absent. For this reason, the percentages were calculated using only the incidences where officers stated that objective signs were present or absent.

The objective signs that were tracked for this study are red eyes, droopy eyelids, hippus, rebound dilation, speech affected, coating on tongue, and the odor of marijuana. Hippus is defined by the DRE protocol as a "rhythmic pulsating of the pupils of the eyes, as they dilate and constrict within fixed limits." Rebound dilation (previously known as pupillary unrest) is defined by the DRE handbook as "a period of constriction followed by dilation with a change equal to or greater than 2 mm" (6). The category of "speech affected" refers to anything that deviates from normal. Common examples are slurred speech, rapid speech, thick speech, and incoherent speech. Any notation about a coating on the tongue was considered for the coating on the tongue category.

Medical Marijuana Cards

In California, use of marijuana for medical purposes has been allowed since 1996 (recreational use became legal in 2016). Officers often ask drivers whether they have a medical marijuana card as part of a routine DUID investigation. In some instances, drivers volunteered that they had a medical marijuana card before being asked by the officer. The number of subjects who claimed to have a medical marijuana card was tracked during the study. In some cases, they provided the medical card to the officer and a photocopy was included in the report. Even those who claimed to have a medical card, but did not prove they had a medical recommendation were counted as having a medical marijuana card in this study. If the medical marijuana card was not specifically mentioned in the report, it was assumed the officer did not ask.

Eye Measurements

Normal pupil size was defined by the DRE protocol. For room light, the normal range is 2.5–5.0 mm. For total darkness, the normal range is 5.0–8.5 mm. For direct light, the normal range is 2.0–4.5 mm. Any measured pupil size that was within the normal ranges was considered normal (5).

Some officers who were not trained DREs mentioned that the subject's eyes were dilated. As no measurements were given, these reported dilations were not used for the purpose of calculations.

Physiological Indicators

The physiological indicators evaluated were pulse and blood pressure. The normal ranges were also defined using the DRE protocol. A normal pulse is 60–90 beats per minutes (5). The first pulse taken from each subject was used to determine averages for the study.

A normal blood pressure is 120–140 (systolic) mm Hg/70–90 (diastolic) mm Hg (5). If more than one measurement for blood pressure was taken by the DRE officer and one measurement was considered high and the other normal, it was rated as high. Conversely, if one measurement was low and the second was normal, it was rated as low. There were no instances within the data set where one measurement was high and the other was low. There were three cases where blood pressure measurements were taken in non-DRE investigations; these cases were not considered when evaluating the statistics for blood pressure.

Both indicators were also evaluated by the THC concentration to determine whether there was a link between physiological indicators and THC concentration. Diastolic and systolic pressures were each plotted versus the concentration of THC found in the blood for each subject to see whether trends emerged. DRE trained officers often report that the difference between diastolic and systolic is a good indicator of THC impairment (vs. other drugs that have elevated blood pressures). Therefore the difference between systolic and diastolic (systolic minus diastolic) pressures was also plotted against the THC concentration for each subject to see whether trends emerged. Pulse was also plotted versus the THC concentration for each subject.

Results

A critical part of the DRE evaluations is that they take place in a controlled environment. As a consequence, DRE evaluations are generally separated from the time of driving by more time than an evaluation that is conducted in the field (non-DRE) as seen in Table 1. The average length of time between the driving time and the time of the field sobriety tests for a non-DRE examination was 33 min, whereas the average time between driving and FSTs for a DRE evaluation was 69 min. The time it takes to get blood drawn after the FSTs is statistically the same for DRE and non-DRE evaluation. This is expected as both use the same technicians to draw the blood. The time it takes from driving (contact) to blood draw is approximately 40 min longer on average for a DRE evaluation. This is reasonable as a DRE evaluation would take approximately that amount of time.

Objective Signs

The prevalence of each of the objective signs observed in this study is presented in Table 2. The presence of objective signs is generally accepted to indicate ingestion, but not necessarily impairment by that substance. For that reason, it is not surprising that the objective signs, with the exception of Hippus and rebound dilation, have very high percentages of prevalence in people who have THC in their system. Several objective signs were evaluated in the 1994 DRE Validation Study (10) and in a 2016 DRE study (11). The prevalence of droopy eyelids, hippus, and rebound dilation found in those studies are presented in Table 2 along with the results from this evaluation.

TABLE 1—*The average time (minutes) for different conditions for DRE and non-DRE evaluations.*

	Drive to FST (min)	FST to Blood (min)	Drive to Blood (min)
DRE evaluations	69	123	193
Non-DRE evaluations	33	121	152

DRE, Drug Recognition Expert; FST, Field Sobriety Test.

TABLE 2—*The presence of objective signs.*

Objective Sign	Number Reported	% Present (*N*)	1994 NHTSA Study	2016 DRE Study
Red eyes	332	94.0 (312)		77.5%
Droopy eyelids	202	85.6 (173)	37%	
Hippus	100	38.0 (38)	20%	
Rebound dilation	118	50.8 (60)	71%	70.9%
Speech affected	283	87.6 (248)		
Coating on tongue	185	96.2 (178)		
Odor of marijuana	363	82.4 (299)		

DRE, Drug Recognition Expert.

Medical Marijuana Cards

When officers asked subjects whether they had a medical marijuana card, 65.7% claimed that they did, while 34.2% said they did not. Officers did not always have to ask the subject about a medical marijuana card to obtain the information. Often, the subjects would announce that they had a medical marijuana card promptly after being pulled over. In 49.3% (n = 179, of 363) of the subjects, officers did not ask whether the driver had a marijuana card. The reasons cited for obtaining a medical marijuana card were varied, ranging from asthma to chronic pain.

Eye Measurements

Per the DRE handbook, it would be expected for a subject under the influence of Marijuana to exhibit dilated pupils. It is also noted that it is possible for pupils to not be dilated when subjects are under the influence of Marijuana. This is supported by the results in Table 3. It is interesting to note that in this study, subjects were more likely to have dilated pupils in room

TABLE 3—*Pupil size comparison for DRE evaluations.*

	Total # of Evaluations	% Dilated (n)	% Not Dilated (n)
Room light	110	63.6 (70)	36.4 (40)
Near darkness	101	13.9 (14)	86.1 (87)
Direct light	108	45.4 (49)	54.6 (59)

TABLE 4—*Pulse measurements (high or low) by evaluation type.*

	% Low (*N*)	% Normal (*N*)	% Elevated (*N*)	Total (*N*)
DRE	0.9 (1)	15.8 (18)	83.3 (95)	114
Non-DRE	0 (0)	7.2 (10)	92.8 (129)	139
Overall	0.4 (1)	11.1 (28)	88.5 (224)	253

DRE, Drug Recognition Expert.

TABLE 5—*Changes in pulse from the first to the second measurement.*

DRE/Non-DRE	Original Pulse	Second Pulse
DRE	100	90
DRE	92	76
DRE	100	90
DRE	96	60
Non-DRE	153	128
Non-DRE	158	136
Non-DRE	160	120
Non-DRE	160	144

DRE, Drug Recognition Expert.

TABLE 6—*Blood pressure for subjects with THC in their system, total* N = *84.*

	% Present	*N*
Low blood pressure	7.1	6
Normal blood pressure	42.4	36
High blood pressure	50.0	42

light than any other lighting condition. It is also important to note that dilated or not was determined using ranges for this study. The percentage of subjects with dilated pupils would likely increase in all categories if just the average value for pupil dilation (per DRE) was used.

The prevalence of conflicting dilation data is often inquired about in court. For example, how often does someone under the influence of Marijauna have dilated pupils in room light and normal pupils in near darkness. In this study, the number of conflicting pupil results was 69 (of 113) which is representative of 61.0% of the cases examined.

Physiological Indicators

A surprising number of non-DRE evaluations included a pulse measurement (139 of 148). This is likely due to training such as the ARIDE (Advanced Roadside Impairment Driving Enforcement) program which serves as a bridge between normal DUI detection and the DRE program by teaching officers to recognize the signs of drug impairment. The majority of subjects with THC in their blood had an elevated pulse as seen in Table 4. DREs found a slightly lower prevalence of elevated pulse. The average for DRE evaluations was 108.8 beats per minute (range 54–160). The average pulse for non-DRE evaluations was 116.7 beats per minute (range 64–180). The overall average was 112.9 beats per minute. The higher pulse rate for non-DRE evaluations is not surprising considering DRE evaluations take place after the initial examination and are therefore farther from the time of ingestion and driving.

A common claim in testimony is that the first pulse was used which can be falsely elevated by the nervousness or excitement of the subject. When evaluating the pulses, it was uncommon for the first pulse to differ greatly from any additional measurements (or to change the categorization from elevated to normal). There were only four instances during the DRE evaluation and four during non-DRE evaluations (total of eight), of 253 evaluations, where there was a significant change from the first pulse to the second pulse. For the four non-DRE evaluations, both measurements were elevated considerably. The changes are detailed in Table 5.

There was no correlation found between the amount of THC in the blood and the pulse rates exhibited in the subjects.

Subjects with THC in their blood had a high blood pressure only 50% of the time (Table 6). Subjects had normal blood pressure in 42.4% of the cases. It was rare in the study (7.1%) for subjects to have a low blood pressure. The average blood pressure in the study was 141/89 which is the top end of the normal range.

There was no correlation found between the amount of THC in the blood and the blood pressure exhibited by subjects. There was also no correlation found between the differences of the two pressures (systolic minus diastolic).

Discussion and Conclusions

Objective Signs

The objective signs of red eyes, droopy eyelids, affected speech, coating on the tongue, and the odor of marijuana are very reliable in indicating the presence of THC in the blood. This is not surprising as they represent the most common symptoms of consuming marijuana.

The prevalence of droopy eyelids is much higher in the current study than was found in the 1994 study. This could be due to a variety of factors including (but not limited to) increased potency, higher THC concentrations in blood, different subjective measures of "droopy," or a higher incidence of droopy eyes not related to THC in the blood. Although droopy eyelids could directly impair the ability to drive by impeding vision, they are not considered evidence of impairment by themselves.

Rebound dilation and hippus are less reliable signs for THC. The DRE handbook states rebound dilation may be present for individuals who are experiencing the effects of THC; Hippus is not expected. Rebound dilation (previously known as pupillary unrest) is defined by the DRE handbook as "a period of constriction followed by dilation with a change equal to or greater than 2 mm." Hippus is defined as a "rhythmic pulsating of the pupils of the eyes, as they dilate and constrict within fixed limits" (6). Clearly these two pupillary reactions are very similar to one another. Since hippus is not expected for an individual with THC in their system and the numbers are low for rebound dilation (only slightly greater than chance), it is possible that the two tests are being used interchangeably in the field. Confusing rebound dilation and hippus has been observed in the field by all three authors. This is supported by the fact that rebound dilation was found in a lower percentage in this study than in the 1994 validation study while Hippus was found in a higher percentage. It is clear that in both studies the likelihood of finding either hippus or rebound dilation is quite high (88.8% in this study, 91% in the 1994 study).

Medical Marijuana

There appears to be a common misconception in the public that the use of medical marijuana does not prohibit the users from driving. This is despite the warnings printed on many of

the recommendations to avoid driving while under the influence of marijuana. It is clear that public education campaigns need to be created to help educate the public on the risks of driving under the influence of marijuana (regardless of the reason ingested). The prevalence of alcohol-related fatalities has decreased as a result of the dual policy of education and penalties. A similar approach needs to be undertaken for marijuana and other potentially impairing drugs.

Eye Measurements

It is clear that dilation of the pupils should not be relied upon to determine the presence of THC as only 63.6% of subjects with THC in their system demonstrated dilated pupils in room light. This is consistent with the DRE matrix which advises that pupils may be normal or dilated.

The dilation of pupils can directly affect the driving behavior itself as it has the potential to increase glare and impair visual acuity of the driver. It is possible that dilation of pupils is not merely consistent with the presence of THC in the blood, but rather it is consistent with impairment by the drug.

Physiological Indicators

The DRE matrix indicates marijuana should cause an elevated pulse. The pulse was elevated in a majority of subjects with THC in their blood, verifying what has been found in numerous other studies. The baseline pulse rate cannot be known for all the subjects in this type of study, making it possible that those in the normal range actually had an elevated pulse and vice versa.

The DRE matrix indicates that subjects under the influence of THC should have an elevated blood pressure. The results in this study were contrary to the DRE matrix as only half of THC-positive subjects had elevated blood pressure. Nearly as many subjects (42.4%) had blood pressure within the normal range. However, the study does not, and cannot, take into account the typical blood pressure of the individual. If someone usually has a low or normal/low blood pressure, the presence of THC might only elevate their pulse to normal or high/normal. Another possible explanation for the lower than expected percentage of subjects with high blood pressure is the amount of time between the ingestion, driving, and blood pressure measurement. Other studies have reported that the diastolic blood pressure decreased significantly from 0.5 to 1 h, and systolic blood pressure was unaffected at all times when looking at chronic cannabis users (16). As the average time to obtain blood was well over an hour, this conclusion would match those found in this study, which would indicate that blood pressure measurements might be useful in determining a smaller window of consumption when present.

It appears elevation of the blood pressure is a valuable tool to predict which category of drug is impairing the individual when it is present, but the absence of high blood pressure does not prove the absence of Marijuana as 49.5% of subjects had normal or low blood pressure in this study.

The delay in DRE evaluations is likely causing officers to miss signs of impairment. In Orange County, due to grants, the percentage of DRE trained officers has increased significantly. Some DRE trained officers are doing near DRE evaluations in the field and then moving to controlled environment and repeating the entire process in a controlled environment. This is likely a better approach, albeit more time-consuming, as it will allow better tracking of potential signs of impairment near the time of driving. It is also a potential area of study to determine which physiological signs are maintained and which change significantly over time.

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