NATIONAL SAFETY COUNCIL

Research Document
Marijuana and Driving
September 2017

TITLE: Cannabis (Marijuana) and Driving

POSITION / POLICY:
Driving under the influence of cannabis[1] is an important public safety concern. Drug impaired driving endangers those both inside and outside the driver's vehicle. Smoking, inhaling or eating cannabis with or without alcohol prior to driving is a common practice and increases the risks of driver impairment, motor vehicle crashes and fatalities. There are also new techniques for administering high doses of the primary psychoactive component of cannabis, ∆9-tetrahydrocannabinol (THC) (e.g. "dabbing" and vaporization of concentrated cannabis extracts in e-cigarettes). THC causes changes in cognitive effects (knowing, thinking, judging, evaluating and planning), and psychomotor effects (coordination, reaction time, motor skills, and tracking).

It is concluded that it is unsafe to operate a vehicle or other complex equipment while under the influence of cannabis, due to the increased risk of death or injury to the operator and the public.

It is further concluded that due to rapid changes in blood THC concentrations over time, there is no minimum safe threshold blood concentration below which a driver can be considered to have been unaffected while driving following recent cannabis use. Consequently, there is no scientific basis for the adoption of THC *per se* laws for driving.

JUSTIFICATION: (Explain the need for and urgency of the issue. Attach supporting pages as necessary)

Nearly two-thirds of U.S. trauma center admissions are due to motor vehicle crashes, with 65.7% of people testing positive for drugs or alcohol (1). In 2013, 10.9% of Americans age 12 or older admitted to driving under the influence of alcohol at least once in the past year, and 9.9 million people reported driving under the influence of illicit drugs (2). Despite real or perceived impairment, individuals did report willingness to drive if they believed they had a good reason to do so, or they believed they had developed tolerance (3,4).

[1] Cannabis is the genus name of marijuana, and is used in the paper to indicate botanical material and products derived from cannabis, including the stems, seeds, flowers and leaves, and extracts including (budder, glass, shatter, butane hash oil (BHO), etc), whether consumed on its own, or mixed or baked into edible products, or drinks.

Alcohol and cannabis are the most frequently detected drugs in drivers (5,6). Cannabis is the most widely-consumed illicit substance worldwide (7). In 2015, the World Drug Report estimated 128-232 million individuals ages 15-64 ingested cannabis. In 2015, 22.2 million U.S. adults 12 years or older smoked cannabis in the last month (7). The 2007 National Roadside Survey (NRS) reported that cannabis was the most common drug found in drivers' blood or oral fluid (OF) with 8.6% of nighttime drivers' positive for THC (5,8). The prevalence of cannabis in nighttime drivers increased to 12.6% in the 2013-2014 NRS, a 48% increase in just six years (9). Twenty-eight U.S. states & Washington, DC passed legislation approving medical cannabis and 8 states & Washington, DC legalized recreational use of cannabis as of December 2016. Recent findings of the 2014 Monitoring the Future Survey funded by the National Institute of Drug Abuse indicated that in U.S. states that legalized cannabis, 40% of high school seniors had used cannabis compared with 26% in states that do not have legalized cannabis (11). Moreover, only 16.4% of high school seniors thought that cannabis smoking puts users at a greater risk for adverse effects. According to the Monitoring the Future national survey results on drug use, 1975-2015: Volume II, 23.4% of high school seniors who responded to a 2011 survey reported using cannabis and then driving; 25% said they rode with someone who had used cannabis and driven. Driving under the influence of cannabis is thus a growing public health concern.

Acute cannabis intoxication produces dose-related impairment in cognitive and psychomotor functioning, as well as risk-taking behavior (12–17). Reaction time (RT), perception, short-term memory and attention, motor skills, tracking, and skilled activities are altered with cannabis intoxication (18–20). These cannabis-induced decrements can impair driving skills.

Early epidemiological studies discussed below had difficulty documenting increased odds ratios[2] (OR) for motor vehicle accidents or driving fatalities for four primary reasons:

(i) The cannabis-exposed group included individuals positive only for THC's inactive metabolite, 11-nor-Δ9-carboxy-THC (THCCOOH), in blood or urine.
(ii) Sample collection was delayed after the event and THC concentrations decrease rapidly.
(iii) There were few cannabis-only cases as many drivers ingested multiple drugs.
(iv) The cannabis-driving population demographics are similar to other high-risk driving populations, young, male, high-risk taking and high incidence of alcohol-impaired driving;

Thus, after adjusting for these confounders, many results were equivocal.

In 2004, Drummer et al. accrued sufficient cannabis-only cases to demonstrate a statistically significant increase in adjusted driver crash responsibility (OR = 2.7) when any blood THC was measureable relative to drug-free drivers (21). The OR increased to 6.6, comparable to culpability associated with a 0.15 g/100mL blood alcohol concentration (BAC), when blood THC was **≥**5 ng/mL. Driving within one hour of smoking cannabis increased crash risk (ORs 1.84 and 2.61) relative to non-cannabis users, even after adjustment for demographic characteristics (22,23). In France, drivers in fatal crashes with detectable THC in blood had a 3.17 OR for crash responsibility (1.7 adjusted for demographics, alcohol

[2] Odds ratio is the risk of an event occurring given a particular exposure, as compared with the risk of an event occurring without that exposure. An odds ratio of greater than 1.00 indicates a possibility of increased risk, and if the 95% confidence interval range exceeds 1.00, this is evidence of increased risk with 95% confidence.

concentration, blood THC concentration, and time of crash) (22). Drivers responsible for a crash have an increased OR with increasing blood THC (Table 1).

Table 1: Crude (adjusted) OR for increasing THC concentrations (23)

Odds Ratio (Adjusted OR)	THC concentration (ng/mL)
2.18 (1.57)	<1
2.54 (1.54)	1-2
3.78 (2.13)	3-4
4.72 (2.12)	≥5

Two recent meta-analyses, each evaluating data from 9 epidemiological studies (only 2 in common) documented significantly increased motor vehicle crash risk even after controlling for confounding variables. The OR and 95% confidence interval (CI) for the studies are noted in Table 2.

Table 2: Increased Motor Vehicle Crash Risk OR and CI Intervals from meta-analyses

Author	Odds Ratio (OR)	CI Interval
Li, et al. (24)	2.66	2.07-3.41
Asbridge, et al. (25)	1.92	1.35-2.73

However, not all epidemiological studies support a significantly increased odds ratio for greater crash risk following cannabis intake. The Driving Under Influence of Drugs, Alcohol and Medicines (DRUID) study conducted in 13 countries in the European Union produced mixed results (26). Due to the low numbers of positive cases and controls the confidence intervals were wide, considered of low accuracy and differed between countries. The crude OR for blood samples containing THC was significantly increased to 1.86 (1.20-2.88), but after adjusting for gender and age, the odds ratio increase was no longer significant (1.38; 0.88-2.17). One important DRUID finding was that the adjusted risk for being responsible for a fatal motor vehicle crash was significantly increased to 1.9 (1.4-2.5) in drivers with THC in their blood.

In addition, the National Highway Traffic Safety Administration's recent case control study of alcohol and drug crash risk preliminarily reported that the drug most frequently used by drivers was THC, detected in 7.6 percent (n = 234) of the crash-involved drivers and 6.1 percent (n = 379) of the control drivers (27). Although this indicated a significantly different proportion of the drivers involved in crashes were THC-positive, (having a significant unadjusted increase in odds ratios of 1.25) when adjusted for age, gender and race, cannabis no longer significantly increased the odds ratio for a crash (1.05; 0.86-1.27). The authors indicated limitations of the study to include a bias toward minor injury crashes and the study was conducted in a single location (Virginia Beach, VA), perhaps limiting generalizability.

Driving simulator studies are useful for measuring THC effects on driving because they have greater validity than laboratory studies of individual psychomotor or cognitive tasks, while eliminating crash risk to participants. Simulators also allow measurement of specific performance decrements in ways unachievable in real-road driving experiments. Reaction time

(RT), road tracking, speed, and standard deviation (SD) of speed were the most commonly measured outcomes. Four of six experiments evaluating RT showed THC dose-dependently increased this measure (28–33). When RT was measured including a secondary task (divided attention), lower (13 and 17 mg) THC doses produced significant and dose-dependent increases, suggesting divided attention is particularly sensitive to THC effects (28).

In a headway maintenance simulator experiment, 19 and 38 mg smoked THC significantly and dose-dependently increased mean and SD of headway[3] relative to placebo (29). The most sensitive road tracking measure was standard deviation of lateral position[4] (SDLP). In one study, 13 and 17 mg smoked THC increased SDLP relative to placebo in light (1-4x/month) smokers, while two other studies showed no significant SDLP increase after 13 mg in individuals smoking 1 to 4 times a month, or after 22.9 mg in those smoking 1 to 10 times a month (28,33,34). In contrast, 19 and 38 mg THC significantly increased SDLP by 4 and 7 cm, respectively (29). Percent time in lane, and "straddled line" demonstrated significant THC-induced impairment 60-330 min and 80 min after doses ranging from 14-52 mg (35,36).

In a 22-km road-tracking closed course test, 100, 200, and 300 µg/kg (~7, ~14, and ~ 21 mg) smoked THC increased SDLP relative to placebo with no significant differences in mean or SD speed (37). A second experiment administered THC (100, 200, 300 µg/kg) in an ascending-dose order for safety reasons. Beginning 45 min after the start of smoking, 16 participants performed a 64 km road tracking segment for approximately 50 min (38). THC increased SDLP in a dose-dependent manner, such that the lowest dose produced a slight and non-significant elevation, the medium dose a significant but modest increase, and the highest dose a highly significant and substantial increase.

Recently, the effects of an illicit drug (cannabis) with and without low dose alcohol (0.05%) on lateral and longitudinal control during driving were demonstrated for the first time in the National Advanced Driving Simulator (NADS) at the University of Iowa following administration of active or placebo alcohol and active (14.5-34.5 mg) or placebo THC to occasional or moderate cannabis users (39). The SD of lateral position (lane weave, SDLP) and steering angle, lane departures/min, and maximum lateral acceleration were evaluated in the same participants. Cannabis and alcohol increased SDLP. Blood THC concentrations of 8.2 and 13.1 ng/mL at the time of driving increased SDLP similar to the most common legal alcohol limits 0.05 and 0.08 g/210 L breath alcohol concentrations, respectively. Cannabis-alcohol SDLP effects were additive rather than synergistic, with 5 ng/mL THC + 0.05 g/210 L alcohol showing similar SDLP to 0.08 g/210 L alcohol alone. Only alcohol increased lateral acceleration and the less sensitive lane departures/min parameters. One of the most important findings of this study was that blood THC concentrations were significantly higher when low dose alcohol was also present (40). Thirty-two adult cannabis smokers (≥1 time/3 months, ≤3 days/week) drank placebo or low dose alcohol (target approximately 0.065% peak breath alcohol concentration) 10 min before inhaling 500 mg placebo, low-dose (2.9%) THC, or high-dose (6.7%) THC vaporized cannabis (6 within-individual alcohol cannabis combinations). Nineteen participants completed all sessions. Median (range) maximum blood concentrations (Cmax) for low and high THC doses (no alcohol) were 32.7 (11.4– 66.2) and 42.2 (15.2–137) ng/mL THC, and with alcohol, low and high

[3] Headway is a measure of the driver's ability to maintain a safe defined distance between their vehicle and the vehicle in front.

[4] SDLP measures the distance from the center of the lane that a driver drifts. It is sometimes referred to as "weaving."

dose Cmax values were 35.3 (13.0 –71.4) and 67.5 (18.1–210) ng/mL THC, significantly higher than without alcohol. It was hypothesized that alcohol increases dilation of blood vessels potentially increasing THC absorption during vaporization.

Another critical finding from this study, was the rapid decrease in THC concentrations from the time of impaired lateral control of driving (41). Blood THC concentrations collected at the time of driving of 8.2 and 13.1 ng/mL produced equivalent impairment on lateral control to 0.05 and 0.08g/210 L breath alcohol concentrations, decreased a median of 73.5% (3.3%–89.5%) without alcohol and 75.1% (11.5%–85.4%) with alcohol in the first half-hour after active cannabis and 90.3% (76.1%–100%) and 91.3% (53.8%–97.0%), respectively, by 1.4 h post-dose. In US driving-under-the-influence cases, blood typically is collected approximately 1.5–4 h after an incident. Forensic blood THC concentrations will be substantially lower than common per se cutoffs at the time of blood collection despite greatly exceeding them at the time of driving (6,42). Unlike alcohol, THC concentrations during driving cannot be reliably back-extrapolated.

Frequent and occasional cannabis smokers residing on a closed research unit smoked as much of one 6.8%THC cannabis cigarette as they desired. Cannabis' psychomotor, neurocognitive, subjective and physiological effects were documented in 11 occasional (<2x/week) and 14 frequent (≥4x/week) smokers (42). Cognitive and psychomotor performance was evaluated with the critical tracking (CTT), divided attention (DAT), nback (working memory) and Balloon Analog Risk (BART) (risk-taking) tasks at -1.75, 1.5, 3.5, 5.5 and 22.5 h after starting smoking. Occasional smokers had significantly more difficulty compensating for CTT tracking error compared with frequent smokers 1.5 h after smoking. Divided attention performance declined significantly especially in occasional smokers for tracking error, hits, false alarms and reaction time. Cannabis smoking did not produce significant effects on the working memory or risk-taking tasks. Suggestion of some tolerance to psychomotor impairment was noted in frequent cannabis users. Blood cannabinoids were quantified on admission (approximately 19 h before), 1 h before, and up to 15 times (0.5–30 h) after smoking (43). Cannabinoid blood concentrations were significantly higher in frequent smokers compared with occasional smokers at most time points for THC and 11-OH-THC and at all-time points for THCCOOH and THCCOO-glucuronide. Cannabidiol, cannabinol, and THC- glucuronide were not significantly different at any time point. For blood THC ≥5 ng/mL, median (range) time of last detection was 3.5 h (1.1–>30 h) in frequent smokers and 1.0 h (0–2.1 h) in 11 occasional smokers. Cannabis smoking history played a major role in cannabinoid detection.

Quantification of multiple OF cannabinoids and understanding differences in OF cannabinoid pharmacokinetics between frequent and occasional smokers improve interpretation of test results on users. A study using OF samples analyzed for multiple cannabinoids showed frequent smokers had significantly greater OF THCCOOH concentrations than occasional smokers at all times, and showed positive results for a significantly longer time(44). Multiple cannabinoid cut-offs were evaluated; the shortest last detection times were observed when THC ≥1µg/L was combined with cannabidiol (CBD) or cannabinol (CBN) ≥1ng/mL. With these cut-offs, last detection times (1-13.5 h) were not significantly different between groups, demonstrating the suitability of these markers for detection of recent cannabis use, independent of smoking history. Cut-offs utilizing THC alone or combined with THCCOOH showed significantly different last detection times between groups. The widest detection windows were observed with THC ≥1 or 2ng/mL or THCCOOH ≥20ng/mL. The data illustrated the

effectiveness of OF as a sample matrix, the impact of self-administered smoked cannabis on OF cannabinoid results, and the ability to improve interpretation and tailor OF cannabinoid cut-offs to support opinions of recent use within a defined window.

The effects of low dose alcohol and cannabis on longitudinal driving control were evaluated (45). In 18 completing drivers, THC was associated with decreased mean speed, increased percent speed low and increased mean following distance during headway maintenance (48). Breath alcohol was associated with increased standard deviation of speed and increased percent speed high, whereas THC was not. A significant THC/breath alcohol interaction was detected in percent of drivers with high speed, suggesting cannabis mitigated drivers' tendency to drive faster after drinking; however, high THC concentrations were required to overcome the drinking driver's tendency to drive fast. Cannabis was associated with slower driving and greater headway, suggesting a possible awareness of impairment and attempt to compensate. Cannabis' effect on longitudinal control (at user preferred recreational doses) was less severe than that of recreational alcohol; but with evidence that cannabis may challenge drivers' overall abilities, requiring additional effort and extra reaction time to adequately perform the driving task than substance-free drivers.

Multiple studies showed increased crash and culpability risks, even after adjusting for potential confounders such as age, sex, risky behaviors, and polydrug use. Elevated blood THC concentrations and driving several hours after smoking were strongly associated with higher crash and culpability risks. Human laboratory controlled drug administration studies showed THC-induced decrements in driving performance began within the first hour and lasted several hours after smoking, consistent with epidemiological data.

Laboratory-based impairment experiments identified divided attention tasks and executive function as being most sensitive to cannabis' effects. Studies evaluating actual driving performance demonstrated dose-dependent THC impairment in road tracking, even following the low to moderate THC doses that were required due to safety concerns.

In addition, The Drug Evaluation and Classification Program (DECP) is commonly utilized in driving under the influence (DUI) cases to help determine category(ies) of impairing drug(s) present in drivers. The most reliable DECP metrics for identifying cannabis-driving impairment were determined from 302 toxicologically-confirmed (blood THC ≥1 µg/L) cannabis-only DECP cases, wherein examiners successfully identified cannabis, compared to normative data (302 non-impaired individuals) (42).

Physiological measures, pupil size/light reaction, and performance on psychophysical tests (one leg stand [OLS], walk and turn [WAT], finger to nose [FTN], Modified Romberg Balance [MRB]) were included. Cases significantly differed from controls
($p<0.05$) in pulse (increased), systolic blood pressure (elevated), and pupil size (dilated). Blood collection time after arrest significantly decreased THC concentrations; no significant differences were detected between cases with blood THC <5 µg/L versus
≥5 µg/L. The FTN best predicted cannabis impairment (sensitivity, specificity, positive/negative predictive value, and efficiency ≥87.1%) utilizing ≥3 misses as the deciding criterion; MRB eyelid tremors produced ≥86.1% for all diagnostic characteristics. Other strong indicators included OLS sway, ≥2 WAT clues, and pupil rebound dilation. Requiring ≥2/4 of: ≥3 FTN misses, MRB eyelid tremors, ≥2 OLS clues, and/or ≥2 WAT clues produced the best results (all

characteristics ≥96.7%). Blood specimens should be collected as early as possible. The frequently-debated 5 ng/mL blood THC *per* se cutoff showed limited relevance. Combined observations on psychophysical and eye exams produced the best cannabis impairment indicators. Similar conclusions were reached in studies of other populations of individuals arrested for driving under the influence of cannabis (6). The authors of that study concluded that in subjects assessed through an examination of physiological and cognitive tests (the DRE exam), there were differences in the presence and degree of indicators of impairment when comparing cannabis positive and cannabis negative subjects. The data failed however to demonstrate any quantitative relationship between the degree of the impairing effect and the subject's blood THC concentration. For example, while subjects with positive THC results (>1ng/mL) showed evidence of impairment, the subjects with THC concentrations above 5ng/mL THC were not predictably more impaired than those with lower concentrations. The authors also noted that among populations of drivers arrested for suspicion of cannabis impaired driving, as few as 30% of these subjects would have been considered impaired under a *per se* standard set at 5ng/mL, depending on whether other alcohol or other drug use is considered. They concluded that a threshold for blood THC concentration-based *per se* laws cannot be scientifically supported. Driving under the influence of cannabis is an important public safety concern.

It is concluded that it is unsafe to operate a vehicle or other complex equipment while under the influence of cannabis, due to the increased risk of death or injury to the operator and the public.

It is further concluded that due to rapid changes in blood THC concentrations over time, there is no minimum safe threshold blood concentration below which a driver can be considered to have been unaffected while driving following recent cannabis use. Consequently, there is no scientific basis for the adoption of THC *per se* laws for driving.

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