

# Marijuana in the Workplace: Guidance for Occupational Health Professionals and Employers

## Joint Guidance Statement of the American Association of Occupational Health Nurses and the American College of Occupational and Environmental Medicine

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**M**arijuana (cannabis) is the most frequently used illicit drug of abuse in the United States and worldwide. Moreover, it is second only to alcohol as the most prevalent psychoactive substance seen in cases of driving under the influence of drugs.<sup>1,2</sup> It is also by a wide margin, the drug most often detected in workplace drug-testing programs. The primary psychoactive substance in marijuana is delta-9-tetrahydrocannabinol, known simply as THC. Present in steadily increasing concentrations in street-purchased, smokeable plant material, the THC content in marijuana averaged 3% in the 1980s, but by 2012 it had increased to 12%.<sup>3</sup>

The US government classifies marijuana as a Schedule I drug (defined as those drugs with no currently accepted medical use and a high potential for abuse,<sup>4</sup> and the use/possession of which is subject to prosecution). Workers covered by federal drug-testing programs are uniformly prohibited from using marijuana at any time. In addition, federal law allows employers in every state to prohibit employees from working while under the influence of marijuana and are permitted to discipline employees who violate this prohibition.

Nevertheless, with public attitudes toward marijuana use changing, prohibitions for its consumption outside of federal law now vary from state to state. Although the possession and use of marijuana continue to be prohibited by federal law, numerous states and the District of Columbia currently have enacted laws regarding marijuana use that conflict with federal law and policy,<sup>5</sup> with legislation pending in other states.<sup>6-8</sup>

This changing legal environment and the evolving scientific evidence of its effectiveness for treatment of select health conditions require an assessment of the safety of marijuana use by the American workforce. Although studies have suggested that marijuana may be used with reasonable safety in some controlled environments, there are potential workplace

consequences involved in its use that warrant scrutiny and concern.

The potential consequences of marijuana use in the workplace include the risk and associated cost of adverse events and the loss of productivity. These safety concerns and the changing legal scene have led the American College of Occupational and Environmental Medicine (ACOEM) and the American Association of Occupational Health Nurses (AAOHN) to develop this guidance document to assist occupational health professionals and employers in identifying and addressing impairment issues related to the use of marijuana and prevention of injuries related to impairment.

This guidance summarizes current evidence regarding marijuana consumption, discusses possible side effects including temporary impairment as it relates to the workplace, reviews existing federal and state laws and legal implications for health care professionals and employers, and suggests various strategies available to employers for monitoring workers for marijuana use. It is outside the scope of this article to address any potential medical benefit of marijuana.

Studies conducted to evaluate the effects of marijuana drug use by workers have demonstrated variable risk. This variability relates to study design, demographics, work type, and potential confounders (eg, general risk-taking behavior among illicit drug users). This discussion on the effects of marijuana is based on a literature search of the currently available evidence (see the Appendix). Articles were graded using the following criteria: inadequate for evidence due to low-quality research; adequate for evidence (+); or high quality (++). High-quality studies, meta-analyses, or multiple adequate studies with the same conclusion qualified as good evidence for the guidance purposes of this document. Statements referring to evidence without a qualifier reflect the results of an adequate study.

Other articles are also cited when appropriate to clarify issues that may not have been addressed by studies qualifying as evidence.

## Legal Implications of Marijuana Legislation

In late 2009, the US Department of Justice initiated a change in marijuana enforcement policy by issuing a memorandum encouraging federal prosecutors not to prosecute individuals who distribute marijuana for medical purposes in accordance with state law.<sup>9</sup> Nevertheless, after voters in Colorado and Washington approved the recreational use of marijuana, the Department of Justice issued another memorandum in August 2013 that reiterated its right to contest the legality of state marijuana laws, stating that the Department “expects states like Colorado and Washington to create strong, state-based enforcement efforts...and will defer the right to challenge their legalization laws at this time.”<sup>10</sup> This discordance about use, regulation, and legislation places employers in the challenging position of maintaining compliance with divergent and evolving legislation, while continuing to provide a safe workplace.

## Americans with Disabilities Act

The Occupational Health and Safety Act of 1970 contains a general duty clause that requires employers under its jurisdiction to, among other things, maintain conditions or adopt practices reasonably necessary and appropriate to protect workers on the job.<sup>11</sup> This duty may necessitate exclusion of those who are impaired or potentially impaired because of marijuana use. As long as marijuana is illegal under federal law, employers who fire or refuse to hire employees for using marijuana are not in violation of the Americans with Disabilities Act (ADA) or any other federal antidiscrimination statute, although there are restrictions on drug testing.<sup>12</sup>

Nevertheless, some states limit employer action against workers who use marijuana according to state standards. If drug testing is done, the decision to test must be job-related and necessary for business, and conducted when there is evidence of a safety or job performance problem. Currently, the ADA does not require employers to permit marijuana use as a reasonable accommodation for an individual with a disability, even if that person is a registered medical marijuana patient. In some states, court rulings involving the use of marijuana for medical purposes have held that employers are under no obligation to accommodate medical marijuana users, regardless of whether or not its use is permitted by state law.<sup>13</sup> The basis of the rulings has been that a person “currently engaging in the illegal use of drugs” is not a “qualified individual with a disability,” and marijuana is still an illegal drug for the purposes of federal law. Nevertheless, the ultimate effects of specific state laws on this issue are yet unknown.<sup>14</sup>

## Drug and Alcohol Testing Regulations

The majority of private employers across the United States are not necessarily required to drug test, and many state and

local governments have statutes that limit or prohibit workplace testing unless required by state or federal regulations due to the nature of the job. Guidance issued by the US Department of Transportation (DOT) for its Drug and Alcohol Testing Regulations state that marijuana use remains unacceptable for any safety-sensitive employee subject to drug testing under DOT regulations.<sup>9</sup> This safety-sensitive category includes pilots, bus and truck drivers, locomotive engineers, subway operators, aircraft maintenance personnel, transit fire-armed security personnel, and ship captains, among others.<sup>9</sup>

Federal agencies conducting drug testing must follow standardized procedures established by the Substance Abuse and Mental Health Services Administration (SAMHSA).<sup>15</sup> Private nonunion employers who require drug testing for applicants and/or employees are usually not required to follow SAMHSA’s guidelines, but doing so helps to ensure the legality of testing. In unionized workforces, the implementation of testing programs must be negotiated through collective bargaining, even when federal regulations require testing.<sup>16</sup>

## Drug-Free Workplace Act

The Drug-Free Workplace Act (DFWA), enacted in 1988 to promote safety and accountability, requires all federal grantees to agree that they will provide drug-free workplaces as a condition of receiving a federal contract of more than \$100,000 or a federal grant of any value.<sup>17</sup> To qualify and remain eligible for federal funds, these entities are required to make continuous good faith efforts to comply with drug-free workplace requirements. The DFWA does not specifically require drug testing, but it does require that employers (1) publish and distribute a policy statement, (2) specify actions that will be taken against employees who violate the policy, and (3) provide education in the workplace about the dangers of drug use and available counseling and employee assistance programs.<sup>9</sup> Employers are not required to fire employees on the basis of the results of a positive drug test. The Act requires employees to abide by the terms of the employer’s policy and notify the employer within 5 calendar days if they are convicted of a criminal drug violation in the workplace.<sup>9</sup> The contracting or granting agency must be notified within 10 days after receiving notice that a covered employee has been convicted of a criminal drug violation in the workplace.<sup>9</sup> Employees who work for federal contractors may be subject to discipline, including termination if marijuana use is proven, regardless of whether its use is permitted by state law.<sup>18</sup>

## Federal Law Enforcement and Transportation of Marijuana Across State Lines

Medical marijuana patients are also subject to federal and local charges of transporting marijuana if they cross state lines with the drug, even if they are traveling between states that allow medical marijuana. As the US Transportation Safety Administration enforces federal rules on commercial airlines, transporting marijuana on an airplane is illegal and can lead to

federal drug transportation charges.<sup>19</sup> Federal agencies may, in some situations, also arrest authorized users.

### State Laws

With so many states and the District of Columbia having enacted medical marijuana laws or decriminalized its use, an employer's legal right to fire or refuse to hire an applicant for failing an employment drug test due to off-the-job medical marijuana use depends on whether the state of employment has passed a medical marijuana law that includes employee discrimination protections. Most states that have legalized medical marijuana do not provide for employee protections, although there are exceptions such as Connecticut, Illinois, Maine, and Rhode Island.<sup>20,21</sup> Michigan protects an employee's rights and safeguards against disciplinary action at work for registered patients, except when a worker uses marijuana on site or comes to work impaired. Arizona and Delaware have more explicit statutory language prohibiting an employer from discriminating against a registered qualifying employee who has failed a drug test for marijuana metabolites or components, except if the employee used, possessed, or was impaired by marijuana at the worksite during work hours, or if failure to dismiss an employee who failed a drug test would violate a contract or licensing-related benefit under federal law.<sup>20</sup>

States that to date have passed laws legalizing recreational marijuana do not provide protections for employee discrimination.<sup>22</sup> Colorado presently allows employers to prohibit the use of marijuana at work. Nevertheless, another state law, the lawful off-duty conduct statute, prohibits employers in this at-will employment state from firing employees for engaging in lawful conduct while off-duty and off premises during nonworking hours.<sup>23</sup> Conflicting legal decisions have arisen with regard to employees who have been fired for testing positive for marijuana, and as of early 2015, this issue is under review by the Colorado Supreme Court. Until state and federal laws coincide, legal challenges and uncertainty in the workplace will continue.<sup>23</sup>

Although state laws vary, laws regulating marijuana require employers neither to permit drug use in the workplace nor to tolerate employees who report to work impaired. For this reason, employers may institute drug-free-workplace policies to help ensure that employees come to work in an unimpaired state and do not endanger themselves or others while working. Reconciling varying and dynamic state laws in regard to legality, permitted use in the workplace, and lawful drug testing can be challenging. Every employer should consult with legal advisors to ensure that they comply with any applicable state or local laws and design their testing programs to withstand legal challenges.<sup>24</sup>

### Medical Issues

Regardless of the legal consequences, the medical implications of marijuana use for the workforce must be considered. In addition to the risk of injury due to impairment,

employers must also consider the possibility that increases in absenteeism and presenteeism may occur as marijuana-containing products become increasingly available to workers.

In 2007, SAMHSA estimated that 8.4% of full-time workers were engaged in some type of illicit drug use within the preceding month.<sup>25</sup> With the legalization of marijuana in certain states, this number could climb. A recent poll found that 9.74% of 534 respondents reported going to work after smoking marijuana (the majority reported obtaining the drug illegally). Although this poll may not reflect the behavior of the US working population as a whole, the data do indicate the need for clear workplace policies addressing workers who use marijuana.<sup>26</sup>

### Metabolism and Impairment

When marijuana is smoked, THC blood levels rise immediately because of efficient pulmonary absorption across the alveolar capillary membrane. THC levels fall rapidly after smoking ceases due to distribution of the substance to the brain and lipophilic tissues, as well as hepatic metabolism.<sup>27</sup> The subjective "high" and associated impairment begins rapidly as well, within minutes of the initiation of smoking when blood levels are rapidly falling and THC is distributed into the central nervous system. Approximately 10% of the absorbed THC is metabolized by the cytochrome P450 (CYP) enzyme system into the equipotent psychoactive metabolite 11-hydroxy-THC (THC-OH), which appears in the blood soon after the THC peak and then falls off rapidly. The major nonpsychoactive metabolite, THC-COOH or carboxy-THC, appears later and can last for several hours or even much longer in long-term users.<sup>28,29</sup> This metabolite is the component commonly assayed in workplace urine drug-testing programs.

Impairment periods vary with the dose administered and the route of administration. For smoked marijuana, subjective impairment begins soon after smoking initiation and peaks in about 1 hour and lasts 3 to 4 hours after smoking. Experimental studies suggest that measurable impairment in test subjects lasts approximately 6 hours.<sup>27,30,31</sup> Many studies focusing on the duration of impairment after acute use were conducted when marijuana typically had a lower THC concentration. Thus, the applicability of these older study results to today's more potent varieties is questionable as the duration of effect may be longer than previously reported.<sup>32,33</sup>

Some studies have demonstrated longer impairment (up to 24 to 48 hours) on specific performance measures, but these studies are limited and the few studies showing this effect used small samples.<sup>34-36</sup> In addition, no comparison of residual peak performance impairment was associated with situations encountered every day and accepted in the workplace (ie, poor sleep the night before, episodic minor illnesses, the use of cold remedies). As described previously, these residual impairment studies were also conducted when cannabis had a much lower potency than what is available today. It is conceivable that residual impairment may actually be more prolonged and problematic with today's higher potency marijuana. The majority

of studies of impairment related to driving and cognition show return to a generally nonimpaired state within 3 to 6 hours after smoking marijuana among occasional recreational users.

Impaired behavior from acute use differs between occasional users and long-term users. There is good evidence that chronic frequent marijuana users exhibit less impairment from acute THC than do occasional users, but the degree to which impairment is mitigated in safety-sensitive activities is unclear.<sup>37-41</sup> This finding can be likened to the chronic drinker who has less apparent intoxication at a given blood alcohol concentration (BAC) than a naive drinker, yet is still acutely impaired.

When marijuana- or THC-containing products are orally ingested, the time to peak blood levels and effects are delayed, with lower peak concentrations and longer duration of effects. Bioavailability varies among marijuana products, owing to the lipophilic nature of THC-products containing more oil or fats tend to increase bioavailability.<sup>27</sup> Bioavailability is also impacted by first-pass hepatic metabolism. Edible products do not allow for a titration effect because users cannot immediately gauge the effect of the dose consumed, and acute psychosis, presumably resulting from the higher dose received via the oral route, has been reported.<sup>42</sup> The subjective “high” after oral administration usually occurs approximately 30 minutes after consumption. There is some evidence that with doses less than 18 mg, impairment decreases to a level of normal performance around 5 hours postingestion.<sup>43</sup> A smaller study of oral ingestion demonstrated impairment of driving skills up to 10 hours after ingestion of higher doses. This impairment did not occur with lower doses.<sup>44</sup> In addition, although a state may have regulations regarding the dose of THC to be used in edible products, it is not clear how this is actually being regulated. Thus, consumers may have difficulty controlling the dose they consume in edibles.

The subjective “high” from acute marijuana use varies with THC concentration, dose, route of administration, and users’ degree of experience with the drug. Common self-described effects are relaxation, euphoria, relaxed inhibitions, sense of well-being, disorientation, altered time and space perception, giddiness, increased appetite, and a more vivid sense of taste, sight, smell, and hearing. Commonly observed central nervous system effects include lack of concentration, impaired learning and memory, alterations in thought formation and expression, drowsiness, and sedation. These psychological effects are accompanied by physiological manifestations of conjunctival injection, a significant increase in heart rate over baseline, dry mouth and throat, increased appetite, and vasodilatation.<sup>40</sup> One study found that pupil dilatation, conjunctival injection, and decreased ocular reaction to light were the physiological symptoms most commonly related to marijuana use.<sup>44</sup> Some of these physiological signs are used by drug recognition expert law enforcement officers who conduct roadside field sobriety tests of suspected drug-impaired drivers.<sup>45-47</sup>

### Assessing Suspected Marijuana Impairment

Although studies that assess impairment in the workplace due to marijuana are now beginning to emerge, numerous

studies using driving simulator, road, and psychometric tests assessing impairment of the skills necessary for safe operation of a motor vehicle caused by cannabis use have been performed. Because much of the knowledge regarding impairment and accident risk in the workplace due to alcohol intoxication has been gleaned from studies of driving impairment and crash risk, these same types of studies can be used to assess impairment in the workplace from cannabis. Numerous experimental studies have been performed to assess the level of driving impairment in relation to the level of THC in serum or plasma. Early studies of crash risk associated with cannabis use failed to show significant impairment in cannabis users because some of these studies used the presence of the inactive carboxy-THC as evidence of drug use. In addition, many potentially culpable drivers had blood for active THC drawn hours after being arrested, and even longer from the occurrence of the motor vehicle crash, allowing metabolism and disappearance of THC from the serum. Multiple studies and meta-analyses of experimental studies, including laboratory, driving simulator, and on-road experiments, found that behavioral and cognitive skills related to driving performance were impaired in a dose-dependent fashion with increasing THC blood levels.

There is good evidence from a meta-analysis and the following real and simulated driving studies indicating that marijuana can negatively affect drivers’ attentiveness, perception of time and speed, and ability to draw on information obtained from experiences.<sup>43</sup> Traffic studies of crash risk have shown that when marijuana was present in drivers’ blood, they were much more likely to be at fault, and there was a dose-response relationship, with drivers having higher THC concentrations being more likely to be deemed culpable for the crash.<sup>2,48-51</sup>

Studies have confirmed that while using cannabis, individuals demonstrate impaired motor performance in both driving simulator and on-the-road tests.<sup>37,52-54</sup> In the driving studies, the strongest decrements were in drivers’ abilities to concentrate and maintain attention, estimate time and distance, and demonstrate coordination on divided attention tasks—all important requirements for operating a motor vehicle.<sup>30,31,35,36,38,55,56</sup>

A large population-based, case-control study of blood levels from more than 10,000 vehicle crashes in France revealed an increased dose-dependent odds ratio for a crash, from 2.18 for THC less than 1 ng/mL, to 4.72 for THC 5 ng/mL or more.<sup>57</sup> Additional studies have found that drivers with a THC-positive blood test were 3 to 6 times more likely to be involved in a crash than drivers without THC.<sup>27,30,31</sup> In a study of impairing effects of marijuana, Ménétrey et al found that any concentration of the psychoactive component was associated with impairment; the impairment of the highest doses was found to correlate with a sum of THC and THC-OH blood concentrations more than 4.6 ng/mL.<sup>44</sup> Another study showed that under experimental conditions, plasma THC higher than a level of approximately 2 to 5 ng/mL established impairment, and levels of THC above 5 to 10 ng/mL, were indicative of

Table 1. Establishing Impairment—Casual vs Long-term User

| THC Plasma Level | Casual User                 | Long-term User              |
|------------------|-----------------------------|-----------------------------|
| 0–2 ng/mL        | Cannot establish impairment | Cannot establish impairment |
| 2–5 ng/mL        | Likely impaired             | May be impaired             |
| 5+ng/mL          | Likely impaired             | Likely impaired             |

THC, delta-9-tetrahydrocannabinol.

severe impairment.<sup>30,31</sup> A Norwegian study found that impaired drivers had, on average, blood THC levels higher than nonimpaired drivers, and those with levels of THC more than 3 ng/mL were at increased risk of being judged impaired.<sup>58</sup>

In summary, there is good evidence from a number of studies and a meta-analysis that serum levels of an average of 3.8 (3.1 to 4.5) for oral and 3.8 (3.3 to 4.5) for smoked marijuana cause impairment approximately equivalent to a BAC of around 0.05 g%. Based on these consistent findings, a plasma level of 5 ng/mL of THC can be used as one indicator with other medical signs of acute impairment from marijuana. The active metabolite THC-OH can also be measured and it may provide additional information regarding impairment. Nevertheless, as the exact level of THC and THC-OH to use as a marker for impairment is not known at this time, the Joint Panel supports the need for further research to define serum levels reflecting impairment and to relate this impairment to chronic daily users. Employers may wish to use the sum of THC and THC-OH to establish impairment because THC-OH is equipotent to THC.

Long-term users are likely to experience less acute impairment by some performance measures, and fewer subjective effects at most of these levels. Using a 5 ng/mL cutoff for screening allows some consideration for all types of users. Given the rough correlation between approximately 4 ng/mL being equivalent in impairing effects to a BAC of approximately 0.04 g% or 0.05 g%, using the 5 ng/mL cutoff seen in the impairment studies noted previously would roughly parallel the current level of alcohol impairment for safety-sensitive workers under federal testing laws (ie, 0.04 g% BAC). Thus, this cutoff may be used to establish an initial presumption of impairment; however, the mere presence of this serum THC and THC-OH level may not establish acute impairment in an individual worker. This can be determined only when a medical evaluation for impairment has been performed in conjunction with consideration of the behavior, which led to the referral for testing.

On the basis of the evidence, the Joint Panel is proposing a serum level of THC plus THC-OH of 5 ng/ml to determine impairment. The Panel acknowledges that there are several states using higher levels for defining driving under the influence of drugs (eg, Colorado and Washington use 5 ng/ml in blood, equal to approximately 10 ng/ml in serum, of THC

and active metabolites as a presumed level for driving under the influence when accompanied by behavior indicating impairment). Fewer than 20 states explicitly address marijuana and driving; of these, 11 have zero tolerance for any level of THC.<sup>59</sup> It is the consensus of the Panel that a serum level of 5 ng/ml should be used to ensure a safe workplace (Table 1).

### Detecting Marijuana Impairment

When a worker is suspected of being impaired by marijuana use, expected signs and symptoms of impairment must be clearly defined in advance and become part of supervisor training, so that reasons for body fluid testing can be documented. This is the same policy as that used for supervisor training in federally regulated drug-testing programs. When impairment is suspected, employees are sent for breath alcohol and urine drug testing. Urine drug testing for marijuana via immunoassay followed by confirmatory GC/MS testing targets the inactive THC-COOH metabolite, which can be present for weeks after last use, and has no correlation with acute impairment. This testing is sufficient for federally regulated programs and in nonregulated environments where all marijuana use is illegal or prohibited by the employer. Nevertheless, a urine drug test showing past use is not sufficient evidence of impairment. Although this use is still prohibited under federally regulated employment programs, this prohibition might not be reasonable or enforceable in nonfederally regulated employer drug testing programs in states with legalized recreational use. Employers choosing to prohibit the use of marijuana during off-work time in states where it is legal should consult with counsel regarding this policy.

Detection of inactive THC metabolites (THC-COOH) in the urine of recreational users after legal use of marijuana would be analogous to detecting ethylglucuronide (ie, EtG—the “80-hour” ethanol metabolite) in the urine of a social drinker. Neither of these results would indicate acute impairment or violation of a law in states where marijuana is legal. For this reason, in states permitting marijuana use, standard workplace urine drug testing of suspected impaired employees would be inadequate. Although breath alcohol devices can be used to detect acute alcohol intoxication noninvasively, psychoactive THC cannot be detected in the same manner and currently requires a blood test. It is suggested that the employee suspected of being impaired be evaluated as per the employer’s standard protocol.

Best practice suggests that employers include an evaluation of the impaired employee at an occupational medicine clinic (or emergency department in off-hours). The evaluation should include a physical examination to determine the presence or absence of clinical impairment, a breath alcohol test, and a urine drug test. To assess for marijuana, a blood test for the cannabinoids THC, THC-OH, and THC-COOH can evaluate potential acute impairment from cannabis use. The employee should be put on administrative leave until these results return, per established protocol. If THC (or THC plus THC-OH levels, for employers who choose to evaluate both psychoactive components) are above a plasma level of 5 ng/mL, the employee is likely acutely impaired by cannabis use. THC levels should never be assessed in isolation—definable signs of impairment (either documented by a supervisor and/or demonstrated on a medical examination) should also be present. Testing of oral fluid, that is, saliva, may prove useful in the future as a screening tool to determine whether further blood testing is necessary.<sup>60</sup>

### Accommodating Marijuana Use In The Workplace: Legal Considerations

Employees who appear to be impaired in the workplace should always be assessed according to employer policies. Urine levels of THC do not correlate with impairment. Blood levels correlate more directly; however, all assessments should include an overall evaluation of impairment. The effect of cannabinoids on impairment includes consideration for the route of administration, concentration of THC, and other variables.

Employers who decide to or are required to accept employees' use of medical and/or recreational marijuana consistent with state law must carefully assess risk of impairment from marijuana use, especially for those employees in safety-sensitive positions. The following guidelines should be observed:

1. A medical review officer (MRO) and other occupational health professionals should be included, with legal counsel, in discussions about company policy or individual use of marijuana.
2. Specific guidelines regarding testing for postaccident and possible impairment assessments should be developed and explained to employees.
  - a. Blood tests are recommended for these assessments and employees should understand the implications of the results for their employment status based on the employers' policy and tolerance for marijuana and other drug use. Most workers' compensation statutes provide reduced benefits when a worker is under the influence of alcohol or illegal drugs. Proof of use and/or impairment may be necessary in these cases.
  - b. The occupational health professional responsible for providing a medical evaluation of employees' fitness for duty should establish and consistently apply clear guidelines on the situations for which use of medical marijuana would be considered. It is advisable for medical evaluations to include:
    - i. documentation of state registration for medical marijuana;
    - ii. the schedule of use relative to working hours;
    - iii. cannabis form used (eg, smoked plant material, edible cannabis product, low THC/CBD product);
    - iv. the need for any accommodations given the employees' job duties; and
    - v. anticipated duration of use.
3. The occupational health provider should work with site management to assess risk based on the safety-sensitive nature of the job. Considerations of workplace safety in the context of the underlying medical condition for which marijuana has been recommended may also be appropriate.

Employees who are included in federal workplace drug testing programs are prohibited from relying on state law as a valid explanation for marijuana or other Schedule I substance positive laboratory results. Nevertheless, employers should be aware that the Food and Drug Administration (FDA)-approved cannabinoid medication dronabinol is a Schedule III medication and, therefore, is not a prohibited substance although it may present a safety concern in some circumstances. Other FDA-approved cannabinoid prescription products may be added in the future; several pharmaceutical cannabinoid products are already available in other countries.

### Development And Management Of A Comprehensive Chemical Impairment Policy—Essential Drug-Testing Considerations

Under Occupational Safety and Health Administration rules, employers have a federal mandate to address impaired workers who contribute to unsafe work environments.<sup>61</sup> The best practice for employers is to begin with a clear written policy regarding chemical use and impairment.<sup>62</sup>

A comprehensive chemical substance policy includes guidelines for fitness-for-duty evaluations and workplace drug testing. An MRO assessment should accompany workplace drug testing. That assessment should be based on a clear understanding between the MRO and the employer regarding policies established by the employer. An MRO is a licensed physician who is certified by an organization approved by the US Department of Health and Human Services. The role of the certified MRO begins with the careful review and verification of laboratory-confirmed drug-test results (most commonly urine test results), particularly those positive results. When a test is positive for THC, the MRO contacts the specimen donor to ask about the last time the donor used marijuana or a cannabinoid product. If the donor denies use or states that it was in the

distant past, the MRO will inquire about legally prescribed medication\* such as Marinol (dronabinol). If that drug has been prescribed, the MRO validates this through the request for documentation of the prescription. Otherwise, the MRO reports the test as positive for THC (or marijuana), whether or not the donor admits using.

In the case of a positive test for marijuana in an individual who is a registered medical marijuana patient, the MRO reports this as a positive test to the employer—it is then up to the employer to determine the employment implications, if any, under company policy and prevailing state law. If the test is done in the regulated environment (eg, DOT testing), the individual must be removed from all safety-sensitive tasks, such as driving a commercial motor vehicle. In the case of an applicant, the individual must not be started on safety-sensitive tasks. Even in the nonregulated testing environment, employers in most states may choose to handle the registered medical marijuana patient with a positive test similar to that of a recreational user (whether legal or not). The employer and the MRO should be versed in their own state's regulations relating to employment protections for the registered medical marijuana patient. In states where this has been challenged, the courts have for the most part ruled in favor of the employer's right to maintain a drug-free workplace and exclude medical marijuana patients with a positive marijuana test, whether or not use occurred just before or during work.

Although no federal laws prohibit testing, several states have passed laws that limit random drug testing for workers in non-safety-sensitive positions.<sup>17</sup> Drug testing is also prohibited in some situations unless there is reasonable suspicion the worker is impaired and unable to perform job duties safely. Therefore, workplace policies that rely on the observation of specific individual behaviors indicating chemical influence or impairment rather than a specific drug test result in isolation may provide a private employer with greater liability protection.<sup>63</sup>

The foundation of a drug-free workplace program is a chemical impairment policy that should be developed, implemented, and evaluated by the human resource (HR) department in consultation with the legal, health and safety, and occupational health departments. Human resource also supports programs to manage employee behavioral problems, including those related to substance abuse. Small business owners without an HR department are also required to follow federal guidelines regarding substance abuse. The DFWA, ADA, Family and Medical Leave Act, and DOT regulations all regulate drug and alcohol impairment in the workplace at the federal level. The HR departments have a responsibility to ensure that company policies and programs are compliant with regulations from these agencies.

\*Marijuana cannot be "prescribed" by physicians or other health care professionals because it is not approved by the US FDA. Only the marijuana-based medications Marinol and Cesamet can be prescribed as they are both FDA-approved.

Drug and alcohol or chemical impairment programs are not required practice for every employer. Nevertheless, some state and federal regulations require programs in specific industries that mandate employee drug testing before and during employment. Employers in some health care and education settings also require workplace drug testing. State regulations control these drug-testing protocols.

In the private sector, state laws requiring drug testing for employees postoffer or after hire may differ from union companies versus nonunion companies. Unless federal regulations require their use, workplace policies on drug testing must be negotiated in union contracts, and even if federally mandated, certain aspects of the policy must be determined through collective bargaining.<sup>17</sup> State laws for medical and recreational marijuana use vary. To better manage litigation risks, employers should consult legal counsel when writing the workplace policy specific to medical marijuana use by employees during the work shift and off the job. Although every policy must be tailored to meet regulations applicable to the specific workplace, employers could use the following content as a foundation for developing workplace policies for medical marijuana and other chemical substances:

- purpose/intent of the program;
- employees covered by the policy;
- when the policy applies;
- prohibited behavior;
- whether employees are required to inform their supervisor of medical marijuana prescription or drug-related convictions;
- whether the policy covers searches and extent of the search allowed;
- observable and measurable behaviors indicative of unsafe job performance;
- referral mechanism for unsafe work performance;
- requirements for drug testing with input from the MRO;
- consequences for policy violation;
- whether return-to-work agreements are needed after an absence related to substance abuse;
- measures to protect employee confidentiality;
- measures for policy enforcement;
- steps to communicate policy to employees, supervisors, occupational health professionals, management, union management when applicable, and contractors and their employees; and
- assistance is available to treat substance use or abuse.

Employers should consult with legal counsel when developing policies regarding employee use of medical marijuana. Historically, employees in safety-sensitive positions have been held to more stringent standards regarding permissible medication use. Thus, a reasonable basis exists for employers to restrict or ban medical marijuana use by these employees. Three states have upheld the employer's right to terminate employees who were using medical marijuana in

accordance with state statutes, even if they were not using it at the workplace. Nevertheless, Arizona currently prohibits termination of employment simply for the medical use of marijuana. The outcome of these legal cases will be determined in appellate courts and is unknown. Equally unclear is whether the ADA may have implications for state-sanctioned medical treatment with marijuana.

Recreational use of marijuana creates another issue as some states have laws that protect employees from termination when they engage in legal activities outside the workplace during nonworking hours. Thus the need for a clear policy and medical assessment of employees who appear to be impaired at the workplace cannot be overemphasized.

## Summary

Employers are often put in a difficult position trying to accommodate state laws that allow the use of marijuana for medical purposes while enforcing federal rules or company drug-use policies based on federal law. To ensure workplace safety as well as compliance with state and federal legislation, employers should review state laws on discrimination against marijuana users and ensure that policies enacted are consistent with the state's antidiscrimination statutes. Although it appears that in most states that allow medical marijuana use, employers can continue enforcing policies banning or restricting the use of marijuana, this approach may change on the basis of future court decisions.

The Joint Task Force recommends that marijuana use be closely monitored for all employees in safety-sensitive positions, whether or not covered by federal drug-testing regulations. Best practice would support employers prohibiting marijuana use at work. Employers, in compliance with applicable state laws, may choose to simply prohibit their employees from working while using or impaired by marijuana. In some states, employers may choose to prohibit marijuana use by all members of their workforce whether on or off duty. Nevertheless, in all cases, a clear policy to guide decisions on when marijuana use is allowed and how to evaluate for impairment must be widely distributed and carefully explained to all workers.

Legal consultation during policy development and continual review is imperative to ensure compliance with federal, state, and case law. Drug-use and drug-testing policies should clearly delineate expectations regarding on-the-job impairment and marijuana use outside of work hours. Specific criteria for use by supervisors and HR personnel when referring employees suspected of impairment for an evaluation by a qualified occupational health professional are critical. Detailed actions based on the medical evaluation results must also be clearly delineated for HRs, supervisors, and workers.

The Joint Task Force recommends that employers review the following points when developing workplace policies that address marijuana use in the workplace:

1. For employees covered by federal drug testing regulations (eg, DOT and other workers under federal

contract), marijuana use, both on or off the job, is prohibited. Thus, employers may use urine drug screening in this population.

2. Employees in safety-sensitive positions must not be impaired at work by any substance, whether it be illicit, legally prescribed, or available over-the-counter. Employers may consider prohibiting on the job marijuana use for all employees in safety-sensitive positions, even when not covered by federal drug testing regulations. Nevertheless, legal review of the employer's policy in the context of state statutes is strongly encouraged. When employers allow medical marijuana use by employees, consultation with a qualified occupational health professional is recommended.
3. Employers residing in or near states that allow the use of recreational marijuana must establish a policy regarding off-work use of marijuana. In many states, the employer may choose to prohibit employees from simply working while using or under the influence of marijuana or may choose to prohibit marijuana use both on and off the job. Urine drug testing above traditional cutoff levels, or serum testing at any level, would be reasonable criteria for the employer wishing to ban both on- and off-the-job use. To detect impairment, a limit of 5 ng/mL of THC measured in serum or plasma as THC (or possibly the sum of THC plus THC-OH for employers who choose to evaluate both psychoactive components) would meet the goal of identifying individuals most likely to be impaired. Nevertheless, employers using the 5 ng/ml level need to understand the limitations of using a single number to fit all cases; therefore, a medical examination focused on identifying impairment is always recommended. Legal consultation is strongly recommended.
4. Although it appears that in most states that allow the use of medical marijuana, employers may be able to continue policies banning or restricting the use of marijuana as previously discussed, this practice may change on the basis of future case law. Currently the ADA does not apply in these situations because marijuana is illegal under federal law. Legal consultation is again strongly recommended.
5. Most workers' compensation statutes allow reduced benefits when a worker is under the influence of alcohol or illegal drugs. Two samples should usually be obtained as a second confirmatory test may be needed. Proof of use and/or impairment is usually required for these cases, and a positive urine drug test (for the inactive metabolite) does not prove acute impairment. The serum level of less than 5 ng/mL could be used for presumptive evidence of impairment in these situations. An MRO is most helpful in helping determine these types of cases because legal testimony may be required.
6. All employers should have clear policies and procedures for supervisors to follow regarding the criteria for identifying potential impairment and the process for



referring an employee suspected of impairment for an occupational medical evaluation. Policies should include action required by HR personnel based on the results of the examination.

7. Employee education is vital to ensure compliance with company expectations. Education is needed at hire and again at regular intervals. Workers must know the company's chemical substance policy and management's expectations for adherence. The employer's commitment to a drug-free workplace and existing company policy will influence the education program's content. At a minimum, employees should learn how chemical substances affect their health, safety, personal behavior, and job performance. Supervisors and employees should also be educated about how to recognize behaviors indicative of impairment, whether the source is medical marijuana, prescription medications, illegal drugs, alcohol, over-the-counter medications, fatigue, or any combination thereof.
8. In states where marijuana use is permitted, employers should provide educational resources regarding the detrimental effects of marijuana use, including caution regarding dose and delayed effects of edible products. This information may be obtained from SAMHSA and state governmental agencies.

The safety of workers and the public must be central to all workplace policies and employers must clearly articulate that legalization of marijuana for recreational or medical use does not negate workplace policies for safe job performance. The evolving legal situation on medical and recreational marijuana

requires employers to consult with legal experts to craft company policy and clarify implications of impaired on-duty workers. This changing environment surrounding marijuana use requires close collaboration between employers, occupational health professionals, and legal experts to ensure that workplace safety is not compromised.

## Appendix

### Evidence Tables

Articles used as evidence were graded using the following criteria: adequate (Grade +) or high-quality (Grade ++). High-quality studies, meta-analyses, or multiple adequate studies with the same conclusion are qualified as good evidence for the purposes of this article. Statements referring to evidence without a qualifier reflected the results of an adequate study. Table A1 lists the articles deemed to be of high or adequate quality and these articles were incorporated into this guidance. Other papers were also cited when appropriate to clarify issues that may not have been addressed by studies qualifying as evidence. In addition, Table A2 includes studies also reviewed by the Joint Task Force but ultimately deemed inadequate for evidence due to low-quality research or found not directly relevant for the purposes of this article.

*Search Strategy: PubMed, EBSCO, and Google Scholar were searched without limits on publication dates. The following search terms were used: THC blood levels and acute impairment, cannabis, driving, illicit,  $\Delta^9$ -Tetrahydrocannabinol, cannabis and dose impairment, THC and dependence, medical marijuana and performance, safety sensitive, toxicology, and driving. A total of 76 articles were identified and reviewed.*

Table A1. High- and Adequate-Quality Studies

| Author (Year), Title, Journal   | Study Type    | Summary of Findings   | Grade |
|---|---------------|---|-------|
| Bergamaschi (2013), Prolonged cannabinoid excretion in chronic daily users: impact on per se drugged driving laws. <i>Clin Chem.</i>  | Cohort study  | Chronic daily marijuana smokers ( $N = 30$ ) tested daily for up to 33 abstinent days found blood levels of THC-COOH can persist for a month whereas 11-OH-THC rapidly extinguishes and is undetectable beyond about 3 days.  | ++    |
| Berghaus (2011), Meta-analysis of empirical studies concerning the effects of medicines and illegal drugs including pharmacokinetics on safe driving. Center for Traffic Sciences, University of Wurzburg | Meta-analysis | Included 78 experimental smoking studies and 21 experimental oral THC studies (all published after 1993). Found that a mean serum THC of 3.7 ng/mL (range, 3.1 to 4.5) for oral THC and a mean serum THC of 3.8 ng/mL (range, 3.3 to 4.5) for smoked THC caused driving impairment equivalent to that of BAC 0.05%. | ++    |

(continued)

Table A1. (continued)

| Author (Year), Title, Journal  | Study Type   | Summary of Findings  | Grade |
|--|--|--|-------|
| Drummer (2004), The involvement of drugs in drivers of motor vehicles killed in Australian road traffic crashes. <i>Accid Anal Prev.</i>                   | Case-controlled culpability study                      | Fatal MVAs examined for driver culpability along with postmortem toxicology screens. Those with blood THC were more likely to be culpable compared with drug/alcohol free, esp. when THC > 5 ng/mL. Combined THC and BAC > 0.05% showed an even greater risk. OR for THC > 5 ng/ml is 6 to 6 (95% CI: 1.5 to 2.8).   | +     |
| Gadegbeku (2011), Responsibility study: main illicit psychoactive substances among car drivers involved in fatal road crashes. <i>Ann Adv Automot Med.</i> | Case-controlled study                                  | Very large case-control study examined car drivers responsible for fatal crashes vs those not responsible. Properly blinded, adjusted for age, sex and alcohol, demonstrated odds ratio of 1.89 (1.43 to 2.51) for cannabis 3 ng/ml and 8.39 (6.95 to 10.11) for alcohol.  | +     |
| Grotenhermen (2007), Developing limits for DUID for cannabis. <i>Addiction.</i>  | Expert panel position paper                            | Similar points as in the author's 2005 publication (see later).  | ++    |
| Grotenhermen (2005), Developing per se limits for DUID for Cannabis. Expert Panel Report   | Expert panel position paper based on systematic review | Relies on epidemiological and experimental science to propose a serum <i>per se</i> limit of 7-10 ng/mL. Authors note that 20 epidemiological studies have inconsistent results with most meaningful showing that under 10 ng/mL (serum) there is no higher crash risk, which increases ~10–20 ng/mL (serum). Impairment acute following use, with no effects on safety beyond acute impairment period (several hours after smoking). More than 120 experimental studies show dose-dependent THC impairment of driving skills, but with considerable individual variability in effect. Tolerance with regular use. Serum levels of 4 ng/mL may correlate with BAC of 0.04%; 9-10 ng/mL (serum) corresponds to BAC of 0.08%. Frequent users may show levels >2 ng/mL (serum) for up to 48 h after the last use. Secondhand marijuana smoke may produce peaks of up to several ng/mL. Depending on dose, most acute effects subside within 3-4 hours of smoking. Most studies find no psychomotor effects after 4 h. Combination with alcohol appears additive. THC-COOH does not indicate acute impairment, but use in prior few days or weeks. Proficiency tests show considerable variation in tests of identical samples in comparing forensic labs—that should be considered in setting limits. | ++    |
| Hart (2001), Effects of acute smoked marijuana on complex cognitive performance. <i>Neuropsychopharmacology.</i>   | Double blinded, placebo-controlled study               | Daily marijuana smokers ( $N = 18$ ) completed neuropsychological battery after smoking 1 marijuana cigarette w/ 0% (placebo), 1.8% and 3.9% THC. Minimal effects on complex cognitive task performance detected (including reaction time, attention, memory, visuospatial processing, reasoning, flexibility). Heart rate and subjective effects correlated with dose.  | ++    |

(continued)

Table A1. (continued)

| Author (Year), Title, Journal  | Study Type  | Summary of Findings   | Grade |
|--|---|---|-------|
| Heustis (2005), THC blood and last marijuana use. <i>Clin Chem.</i>  | Cohort study  | Cohort of 38 patients inhaling marijuana and timed serum levels measured. Generated model of rate of metabolism from the time of inhalation. Time of inhalation needed to estimate level at desired time in past. Model used in more recent studies by Heustis.   | ++    |
| Hunault (2009), Cognitive and psychomotor effects after marijuana smoking. <i>Psychopharmacology.</i>  | Double-blinded, placebo-controlled randomized study | Nondaily marijuana users ( $N = 24$ ) who smoked high THC content cigarettes (mixed with tobacco) evaluated for psychomotor/cognitive effects. Linear increase in response time and motor impairment; 4 did not demonstrate dose-effect relationship—authors postulate either tolerance or innate differences as explanation and note that despite levels as high as 40 $\mu\text{g/L}$ , some subjects showed no impairment; thus, no definite conclusions can be drawn on possible psychomotor impairment based on THC serum levels for such subjects. Authors conclude that smoking high THC marijuana without titration of effect may pose greater safety and public health concerns. | ++    |
| Jones (2008), Driving under the influence of cannabis: a 10-year study of age and gender differences in the concentrations of tetrahydrocannabinol in blood. <i>Addiction.</i> | Retrospective cross-sectional analysis              | Shows serum THC concentration in 8794 cases of Swedish population stopped for suspected DUID and tested. Shows large skew to the left 43% < 1 ng/mL. Mean 2.1, median 1, max 67 ng/mL. Implies that because of rapid metabolism of inhaled marijuana, it is difficult to correlate with level of impairment. Advocates zero tolerance.  | ++    |
| Karschner (2009), Implications of plasma cannabinoid concentrations in chronic users. <i>J Anal Tox.</i>   | Cohort study  | Eighteen (18) heavy, chronic marijuana users had daily marijuana levels drawn while drug free for 7 days; 50% maintained positive levels for 7 days. One level is as high as 5.5. Levels are not predictive of time of last consumption. No correlation with BMI.   | +     |
| Karschner (2009), Do $\Delta^9$ -tetrahydrocannabinol concentrations indicate recent use in chronic cannabis users? <i>Addiction.</i>  | Cohort study  | Chronic marijuana users ( $N = 25$ ) monitored over 7 days of abstinence. Nine (9) had no measurable amount, and 6 had measurable THC amounts on day 7. Indicates substantial amounts of THC left in blood in long-term users.  | +     |
| Khiabani (2006), Relationship between THC concentration in blood and impairment in apprehended drivers. <i>Traffic Inj Prev.</i>   | Cross-sectional study                               | Study investigated whether a physician's judgment on impairment in a real-life setting among suspected drugged drivers was related to blood THC concentration. Relationship between concentration of THC in blood and risk of being assessed impaired supports findings from previous experimental studies of concentration related effects of THC on psychomotor performance and driving skills.   | +     |

(continued)

Table A1. (continued)

| Author (Year), Title, Journal  | Study Type   | Summary of Findings   | Grade |
|--|--|---|-------|
| Laumon (2005), Cannabis intoxication and fatal road crashes in France: population based case-control study. <i>BMJ</i> .   | Population-based, case-controlled study                    | See Gadegbeku (2011). A large study of 10,748 drivers, with known drug and alcohol concentrations involved in fatal crashes in France from October 2001 to September 2003. Positive cannabis detection was associated with increased risk of responsibility (odds ratio = 3.32; 95% CI: 2.63-4.18).   | +     |
| Liguori (1998), Effects of marijuana on equilibrium, psychomotor performance, and simulator driving. <i>Behav Pharmacol</i> .  | Cohort study   | Ten subjects inhaled low-dose (1.77%) or high-dose (3.95%) marijuana and then took a battery of tests. High, but not low, dose increased body sway and brake latency. Effects similar to results of BAC of 0.05%.   | +     |
| Liguori (2002), Separate and combined effects alcohol, marijuana impairment driving simulator. <i>Psychopharm</i> .  | Cohort study   | Subjects ( $N = 12$ ) given different concentrations of EtOH followed by marijuana cigarette. Given equilibrium test (body sway) and then driving performance test (brake latency). No significant additive effects of THC to potentiate the effects of EtOH on these tests. Also no potentiation of perception of impairment in EtOH and TCH.  | +     |
| Menetrey (2005), Driving skills of psychometric tests and blood THC following oral THC. <i>J Anal Tox</i> .  | Prospective case-controlled study individuals own controls | Oral Dronabinol and Hemp concoctions given to eight male long-term users. Blood levels measured over time and compared with degree of driving impairment and self-perception of safety. Significant levels present at 10 h postingestion. Higher oral ingestion of 45.7 mg demonstrated continued impairment at 10 h. THCOOH/THC ratio more reliable measure of metabolism postexposure. More accurate than THC and tends to underestimate exposure time. | +     |
| Mura (2003), Comparison of the prevalence of alcohol, cannabis and other drugs in 900 injured drivers and controls subjects: results of a French collaborative study. <i>Forensic Sci Intl</i> .             | Collaborative case-controlled study                        | Examined prevalence rates of THC, EtOH, and other drugs in serum of ER patients for traumatic vs rates in nontraumatic patients (controls). Higher prevalence of THC 10% vs 5% of controls.   | +     |
| Papafotiou (2005), The relationship between performance on the standardized field sobriety tests, driving performance and the level of $\Delta^9$ -tetrahydrocannabinol in blood. <i>Forensic Sci Intl</i> . | Cohort study   | Goal to determine whether impairment on sobriety test (ST) and head movement test (HMT) from THC effects also impairs driving performance test. Marijuana users ( $N = 40$ ) smoked 0 dose, 1.74% THC, or 2.93% THC. Then, ST + HMT followed by driving test. At 50 min, 88% impaired ST; 38% of nonimpaired drivers correctly identified with ST. Suggests ST as screen for marijuana performance affected use.  | ++    |

(continued)

Table A1. (continued)

| Author (Year), Title, Journal   | Study Type  | Summary of Findings   | Grade |
|---|---|---|-------|
| Ramaekers (2006), High-potency marijuana impairs executive function and inhibitory motor control. <i>Neuropsychopharmacology</i> .  | Double-blinded, placebo-controlled, crossover study | Single doses of 0, 250, 500 µg/kg THC given to 20 recreational marijuana users. Performance tests conducted at regular intervals between 15 min and 6 h postsmoking and included measures of motor control, executive function, motor impulsivity, and risk taking. THC-induced impairments lasted up to 6 h postsmoking as indicated by absence of THC × Time after smoking interaction. Data suggest that high potency marijuana consistently impairs executive function and motor control.   | ++    |
| Ramaekers (2006), Cognitive and motor control as a function of THC concentration in serum and oral fluid: limits of impairment. <i>Drug Alcohol Depend.</i>   | Double-blinded, placebo-controlled, crossover study | See the aforementioned study.   | ++    |
| Ramaekers (2009), Neurocognitive performance during acute THC intoxication in heavy and occasional cannabis users. <i>J Psychopharmacology</i> .  | Double-blinded, placebo-controlled, crossover study | Twelve (12) occasional and 12 heavy users smoked 500 µg/kg (35 mg for a 70-kg subject) THC or placebo by standardized smoking procedure. Performance on various psychomotor tasks and serum THC levels measured at baseline and over 8 h postadministration. Occasional users showed significant impairment on most tasks at serum THC levels ≤ 10 ng/mL and on all tasks at THC levels > 10 ng/mL. Heavy users showed only significant impairment on the stop signal task (increased reaction time) at THC levels >10 ng/mL.   | ++    |
| Schwope (2012), Psychomotor performance, subjective and physiological effects and whole blood delta-9-tetrahydrocannabinol concentrations in heavy, chronic cannabis smokers following acute smoked cannabis. <i>J Anal Toxicol</i> . | Cohort study  | Nine male/1 female heavy, chronic cannabis smokers in closed research unit smoked ad libitum one 6.8% THC cannabis cigarette. THC, 11-hydroxy-THC and 11-nor-9-carboxy-THC quantified in whole blood and plasma. Assessments: subjective (VAS and Likert scales); physiological (heart rate, blood pressure, respirations); psychomotor (critical-tracking and divided-attention tasks) performed before/up to 6 h after smoking. THC significantly increased VAS responses and heart rate, with concentration-effect curves demonstrating counterclockwise hysteresis. No significant differences observed for critical-tracking or divided-attention task performance. Cannabis influence factor not suitable for quantifying psychomotor impairment following consumption and not precise enough to determine recent cannabis use with accuracy. | +     |

(continued)

Table A1. (continued)

| Author (Year), Title, Journal   | Study Type   | Summary of Findings  | Grade    |
|---|--|--|----------|
| <p>Skopp (2008) Cannabinoids concentrations in spot serum samples 24-48 hours after discontinuation of cannabis smoking. <i>J Anal Toxicol</i>.</p> | <p>Case series</p>   | <p>Inpatients (<math>N = 37</math>) on closed detox ward for opioid dependence divided into 3 groups based on marijuana use: (1) heavy users (&gt;1 joint/day—<math>N = 16</math>); (2) moderate users (up to 1 joint/day—<math>N = 15</math>); and (3) light users (up to 1 joint/week—<math>N = 6</math>); 29 blood samples for THC, THC-OH, and THC-COOH drawn 24 to 48 h after abstaining from cannabis use; 4 samples &gt;48 h after the last use from heavy and moderate users. Impairment signs and subjects' personal assessment of being "high" recorded at the time of blood sampling. No subject deemed to have drug effect by clinical signs or subjective rating. No specific tests for evidence of impairment performed; 8 specimens from 16 heavy users tested positive for THC (range: 1.2 to 6.4 ng/mL) 24 to 48 h after cessation of drug use; 5 positive for THC-OH (0.3 to 2.4 ng/mL). One specimen from subject with BMI of 30.7 contained THC and OH-THC 120 h after smoking. THC detectable in 6 of 15 moderate users in range of 0.3 to 2.6 ng/mL, THC-OH present in three samples (range, 0.3 to 1.2 ng/mL). None positive for active component &gt;48 h after cessation. One specimen of 6 light users positive for THC (1.4 ng/mL); all negative for THC-OH. Authors conclude that findings of blood levels of psychoactive components of cannabis (THC and THC-OH) may not unequivocally prove recent use of cannabis because these components are detectable 24 to 48 h after abstaining from cannabis use in some heavy and moderate cannabis users.</p> | <p>+</p> |
| <p>Spronk (2011), Acute effects of delta-9-tetrahydrocannabinol on performance monitoring in healthy volunteers. <i>Front Behav Sci</i>.</p>        | <p>Randomized double-blinded, placebo-controlled crossover study</p> | <p>Ten study subjects given vaporized THC in ethanol or vaporized ethanol alone on separate occasions, each serving as his own control in a crossover design. On separate study days, each received three subsequent doses of THC (4 mg, 6 mg, and 6 mg) at 90-min intervals, or placebo on placebo day. Subjects and investigators blinded to active THC vs placebo control administration. EEG monitoring while performing modified Flankers task. Blood for THC drawn at 5, 20, 95, 110, 185, and 200 min after initial THC administration. Found ERN amplitude on EEG significantly reduced after administration of THC, indicating that THC impairs performance monitoring. Task not designed to detect behavioral effects.</p>   | <p>+</p> |

(continued)

Table A1. (continued)

| Author (Year), Title, Journal   | Study Type  | Summary of Findings   | Grade |
|---|---|---|-------|
| Theunissen (2012), Neurophysiological functioning of occasional and heavy cannabis users during THC intoxication. <i>Psychopharmacology</i> . | Double blinded, placebo-controlled, crossover study | Tested 12 heavy marijuana users and 12 occasional users on Divided Attention Test (DAT) and Stop Signal Testing (SST) while performing EEG monitoring to discover if EEG evidence of differences in Event-Related Potentials (ERPs) between groups performing these tasks. Subject served as own control as on 1 occasion received a placebo cigarette. Investigators and subjects blinded to active/placebo days. Occasional users impaired on DAT, heavy users had some tolerance to acute intoxicating effects on DAT; both groups impaired on SST, specifically increased stop reaction times in heavy and occasional users. Findings confirmed by ERPs on EEGs. Specifically, P100 ERP showed adaptation/tolerance in heavy users but not occasional users, whereas P300 ERP proved a sensitive measure of intoxication in both groups. THC concentrations in blood positively correlated with SST reaction time, which is a measure of impulse control.   | +     |
| Van Elsland (2012), Influence of cannabis on fatal traffic crash: a detailed analysis. <i>Transp Res Rec</i> .                                | Retrospective cohort                                | Reanalysis of SAM database of fatal crashes in France 2001-2003, an overall sample of 16,705 who had blood tests for drugs and alcohol. Original study showed dose effect of cannabis with an excess risk of 1.5 for THC blood level <1 ng/mL (reaches 2.12 for THC level >5 ng/mL). Reanalysis evaluated human functional failures of drivers with cannabis-only + tests with controls of age-matched drivers with no drugs detected. Analysts were blinded to cannabis status of all drivers. Generalized alteration of sensorimotor/cognitive capacities most common failure among cannabis drivers. Drivers with generalized sensorimotor alteration: median THC level 16.2 ng/mL vs THC of 2.5 ng/mL for drivers committing other failures; 78% committing generalized sensorimotor errors had THC >5 ng/mL. Errors accounted for 18.4% of fatal crashes. Cannabis + drivers significantly more likely to have low level of physiological vigilance and attention, more likely to engage in risky driving behaviors. Threshold effect of blood THC levels: THC <5 ng/mL conventional functional failure (alteration of 1 specific function); THC >5 ng/mL extreme failure leading to breakdown of all functions required for safe driving and vehicle control loss. Also, 13.2% cannabis drivers unable to properly evaluate road infrastructure vs 5.7% controls. Cannabis drivers significantly more likely to be involved in single vehicle crashes; trend increased with increasing THC levels: 40% of single-vehicle crash drivers had THC >5 ng/mL, and 63% of drivers with THC >5 ng/mL lost control of vehicles. In contrast, 65% of control group crashes involved another vehicle. | +     |

(continued)

Table A1. (continued)

| Author (Year), Title, Journal  | Study Type   | Summary of Findings  | Grade |
|--|--|--|-------|
| Weinstein (2008), A study investigating the acute dose–response effects of 13 mg and 17 mg Δ-9-tetrahydrocannabinol on cognitive-motor skills, subjective and autonomic measures in regular users of marijuana. <i>J Psychopharmacol</i> . | Double-blinded, placebo-controlled crossover study | Fourteen (14) daily users administered a 17-mg THC cigarette on first day and performance measured on several psychomotor tasks 2 h later (inadequate washout time). Subjects then received a placebo cigarette and same performance tasks repeated. On second study day (1 week after first), each subject administered a placebo cigarette and underwent various psychomotor tests. Received 13-mg THC cigarette 2 h later and repeated tasks. Performance significantly affected after 17-mg THC compared to placebo and to 13-mg THC on one task; significantly lower for both THC doses compared to placebo on another. Other tasks did not show significant drug effects. No comparison to occasional users. | +     |
| Yesavage (1985), Carry-over effect of marijuana intoxication on aircraft pilot performance. <i>Am J Psychiatry</i> .   | Controlled clinical trial, single blinded          | Ten experienced private pilots tested on flight simulator landing task. Each served as own baseline performing task prior to THC administration and then tested 1, 4, and 24 h after smoking 19-mg THC cigarette. Each had significant subjective and measured impairment at 1 and 4 h. Final test at 24 h trended toward impairment on all variables with significant impairment in a number of measures. No report of subjective impairment or any awareness of impaired performance on simulated landing. It is unknown how these simulator tests directly relate to common safety-sensitive jobs.  | +     |

BAC, blood alcohol concentration; CI, confidence interval; EEG, electroencephalogram; MVA, motor vehicle accident; OR, odds ratio; THC, delta-9-tetrahydrocannabinol.

Table A2. Low Quality/Additional Articles Reviewed

| Author (Year), Title, Journal   | Study Type       | Summary of Findings  |
|---|------------------|--|
| Aggarwal (2007), Dosing medical marijuana: rational guidelines on trial in Washington State. <i>Medscape</i> .  | Editorial        | Proposes amounts for a 60-d supply for a medical marijuana patient.  |
| Armentano (2013), Cannabis and psychomotor performance: a rational review of the evidence and implications for public policy. <i>Drug Test Anal</i> . | Editorial review | While EtOH accident risk is well established, THC role is less clear. Accident risk appears to be dose dependent, and most likely when there are unexpected changes in the driving environment that require complex psychomotor response. Concerns about <i>per se</i> levels include peak levels not corresponding to behavioral impairment, wide variations in psychomotor effects of THC, especially among naive subjects, and residual levels may persist for days. Recommends increased efforts to research and apply field sobriety type tests rather than using THC levels for establishing driving impairment. |

(continued)



Table A2. (continued)

| Author (Year), Title, Journal  | Study Type                             | Summary of Findings   |
|--|--|---|
| Armentano-Humboldt (2013), Should <i>per se</i> limits be imposed for cannabis- equating THC levels with actual driver impairment. <i>J Soc Relat.</i> | Editorial review                       | Good editorial review that distinguishes “effect based DUI laws” (based on actual psychomotor impairment) from “ <i>per se</i> ” laws (either zero tolerance or specific levels). Notes scientific consensus for specific blood-alcohol levels and performance impairment, but not for THC. Peak THC blood levels do not correlate with maximum levels of impairment. Maximum effect of smoked marijuana is 20 to 40 minutes after smoking, diminishing 60 to 150 minutes later. Notes that THC-OH is psychoactive with detection up to 6 h after smoking. THC-COOH is not psychoactive and can be present for days or weeks in plasma. Oral ingestion peaks about 60–120 min after dosing and declines over several hours. Recent use by an occasional user difficult to distinguish from prior use by a long-term user due to lipid solubility and variable pharmacokinetics of THC. Thus, “it is difficult to establish a relationship between a person’s THC blood or plasma concentration and performance impairing effects.” Points out lack of consensus regarding plasma concentrations linked with impairment, studies showing divergent results, interindividual variability in effects, and tolerance of long-term users. All these factors limit scientific support for <i>per se</i> levels. |
| Asbridge (2012), Cannabis and MVA risk: a meta-analysis. <i>BMJ.</i>   | Meta-analysis of observational studies | Nine studies reviewed; OR of 1.92 for motor vehicle crashes (MVCs) while driving under influence of cannabis. Collision risk higher for case-control studies and fatality studies vs culpability studies and studies of nonfatal collisions. Acute marijuana use doubles risk of MVC with serious injury or death. Impact of marijuana use on minor crashes is unclear. Association of MVC with marijuana less robust than EtOH, which is most prevalent substance present in crashes. While not a research study, it is a good quality review.   |
| Bates (1999), Role of cannabis in motor vehicle crashes. <i>Epi Rev.</i>   | Review                                 | Older reviewer notes that although marijuana impairs driving performance, this is ameliorated by drivers’ awareness of their impairment, leading to compensatory, less-risky behavior. Nevertheless, this is not effective when events are unexpected or continuous attention required. Marijuana users drive slower, increase following distance, have increased reaction time, and may show impaired emergency behavior. Overall, no evidence THC alone increased risk of culpability for MVC fatalities or hospitalizations. Combined THC/EtOH does increase this risk. Not known if THC affects risk of less serious MVCs.  |

(continued)

Table A2. (continued)

| Author (Year), Title, Journal  | Study Type  | Summary of Findings  |
|--|---|--|
| Berghaus (1995), Effects of cannabis on psychomotor skills and driving performance: a meta-analysis of experimental studies. <i>Proc Int Councl Alc Drugs Traffic Safety Conf.</i> | Meta-analysis   | Variety of performance areas related to driving affected by THC: tracking, psychomotor skills, reaction time, visual functions, attention, and performance in simulated and real driving. Effects tended to be concentrated in first 2 h after smoking and was dose dependent. Frequent users are less impaired. Impairing effects tended to be subjectively overestimated, resulting in a greater ability to compensate compared with EtOH users. Peak effect lags behind peak blood level. Good-quality review of 60 experimental studies of smoked marijuana found that 50% of cumulated performance results showed significant decrements at 6 ng/mL plasma THC for tracking, 8 ng/mL for psychomotor skills, 9 ng/mL for attention, 11 ng/mL for divided attention, and 11 ng/mL for all performance areas taken together. Frequent users showed less impairment than occasional users. |
| Bolla (2002), Dose-related neurocognitive effects of marijuana use. <i>Neurology.</i>  | Cohort study  | A neuropsychological battery applied to 22 heavy chronic marijuana smokers after 28 days of abstinence found persistent deficits in performance. Association not determined to be causal. No control or light-smoking groups and no baseline tests done (only tested after 28 days). Various other study limitations preclude generalizing the results. Low-quality study.   |
| Bosker (2013), Psychomotor function in chronic daily cannabis smokers during sustained abstinence. <i>PLoS ONE.</i>  | Cohort study using unmatched controls                 | Nineteen (19) chronic daily marijuana smokers (mean 10.9 joints per day) underwent 3 weeks of abstinence on an inpatient unit. Performance on 2 psychomotor tasks measured at the beginning of abstinence and weekly for 3 weeks. Performance compared to placebo performance of controls ( $N = 30$ ) who were occasional users (not matched for potential confounders). Chronic daily users' performance improved over 3 weeks of abstinence but remained significantly worse than controls' performance. Results suggest that chronic heavy users may be chronically impaired, apart from any acute THC-induced impairment.   |
| Bramness (2010), Impairment due to marijuana and EtOH—clinical signs and additive effects. <i>Addiction.</i>   | Retrospective cross-sectional forensic database study | Norwegian drivers stopped by police for suspected DUI: 3480 + EtOH only; 589 + THC only; 894 + both; 79 negative. Subjects evaluated by police physician using Norwegian Clinical Test for Impairment (CTI). Relationship with blood THC level only seen for ocular tests. All levels of THC alone associated with CTI determination of impairment, but to a smaller extent than EtOH (even at EtOH levels lower than 0.025). Impairment of safe driving and task performance is not clearly defined in the article.   |

(continued)

Table A2. (continued)

| Author (Year), Title, Journal  | Study Type                                     | Summary of Findings  |
|--|--|--|
| Braun (1998), Marijuana use and medically attended events. <i>Ann Emerg Med</i> .  | Cohort study                                   | Random sample of 4462 health plan members with baseline self-reported marijuana use data followed for 3 yrs to document medical visits for injuries. Chart abstracters blinded to marijuana use. No difference between marijuana users and nonusers with regard to medically attended injuries. Self-reported use may have caused degree of misclassification.   |
| Brookoff (1998), Marijuana and injury: is there a connection? <i>Ann Emerg Med</i> .   | Editorial                                      | Commentary on Braun paper—Notes some of the study limitations and that there is a “pressing need for high-quality research on the potential connection between marijuana use and injury. Very few police departments are equipped to test impaired drivers for marijuana, and the value of toxicological testing for marijuana remains controversial.  |
| Budney (2002), Cannabis dependence. <i>Clin Pharm</i>  | Review   | Focused on the question of cannabis dependence; not directly relevant.   |
| Chait (1989), <i>Delta-9-tetrahydrocannabinol content and human marijuana self-administration</i> . <i>Psychopharmacol</i> (Berl).   | Cohort study                                   | Small study of 10 regular marijuana smokers, each of whom was allowed to self-administer marijuana of low, medium, or high THC content freely over 30-min period. No differences among the three potencies of marijuana in postsmoking CO boost. Tolerance was observed over course of the study to the heart rate increasing effect of marijuana. Results indicate that subjects failed to regulate their intake of marijuana smoke in response to substantial (4-fold) changes in marijuana THC content. |
| Downey (2013), Effects of marijuana and EtOH on driving simulators. <i>Accid Anal Prev</i> .   | Case-control study                             | Double-blinded counterbalanced placebo-controlled study of the effects of a combination of EtOH and cannabis on simulated driving. Noted that simulated driving was more impaired with EtOH and blood level of THC higher with EtOH.   |
| Elvik (2012), Risk of road accident associated with the use of drugs: a systematic review and meta-analysis of evidence from epidemiological studies. <i>Accid Anal Prev</i> . | Systematic review, meta-analysis of literature | Good-quality review that analyzed 66 studies looking at a variety of different drugs. In general, found modest effects in comparison with EtOH. Publication bias detected for some drugs. Higher-quality studies tend to show lower estimates of risk. Associations cannot be established as causal.   |
| Favrat (2005), Two cases of “cannabis acute psychosis” following the administration of oral cannabis. <i>BMC Psych</i> .   | Case report                                    | Report of 2 cases of 8 healthy male occasional but regular cannabis users without psychiatric history who developed transient psychotic symptoms (depersonalization, paranoid feelings, derealization) following oral administration of cannabis conducted under experimental conditions. Authors concluded that while oral route of administration achieves only limited blood concentrations, significant psychotic reactions may occur.   |

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Table A2. (continued)

| Author (Year), Title, Journal   | Study Type   | Summary of Findings  |
|---|--------------|--|
| Fletcher (1996), Cognitive correlates of long-term cannabis use. <i>Arch Gen Psych</i> .  | Cohort study | Long-term cannabis users compared with demographically comparable nonusers on a variety of memory/attention tests. Long-term users performed more poorly on short-term memory, working memory, and attention tests. May have been certain biases in subject selection; difficult to generalize these results. Relevance to this position paper limited.  |
| Grotenhermen (2005), Cannabinoids. <i>Curr Drug Targets</i> .   | Review       | General review of the pharmacology of cannabinoids.  |
| Hall (2009), Health effects of non-medical THC use. <i>Lancet</i> .   | Review       | A review of various health effects of cannabis.  |
| Hartman (2013), Cannabis effects on driving. <i>Clin Chem</i> .   | Review       | Comprehensive literature review on relationship of cannabis and driving: cannabis consumption associated with motor vehicle accident usually not significant. Driving under the influence of cannabis significant. Urine level not significant. Adjusted OR = 8.6 for >5 ng/mL marijuana users for driving fatalities. Drivers claiming regular cannabis use had less impairment than occasional users for given THC level. Presents a summary of literature on which tests are affected by marijuana use.   |
| Heishman (1997), Comparative effects of alcohol and THC on mood, memory, performance. <i>Pharm Bio Behav</i> .  | Cohort study | Five subjects given different concentrations of EtOH and marijuana concentrations and placebo. Tests of memory and dexterity. Both tests had effects on digit symbol substitution and word recall. Too small a study to use beyond pilot-level information.  |
| Heishman (1990), Acute and residual effect of marijuana; profiles of plasma THC levels, physiologic, subjective, and performance measures. <i>Pharm Biochem Behav</i> . | Cohort study | Three subjects inhaled marijuana and physiological parameters measured over 48 h. Impairment in cognition, recall and physiological effects (tachycardia) were impaired for up to 24 h. Too small a study to use beyond pilot-level information.   |
| Huestis (2007), Human cannabinoid pharmacokinetics. <i>Chem Biodiversity</i> .  | Review       | Article discusses pharmacokinetics of TCH—found to have predictable models of last marijuana use using TCH-COOH/THC ratios. Urine measurements currently unreliable.   |
| Huestis (2013), Cannabis effect on driving skills. <i>Clin Chem</i> .   | Review       | Comprehensive review of effects marijuana on being in a motor vehicle accident (MVA). Serum sample obtained occurs 4 h after accident—many results negative at that time. DUIC within an hour of THC inhalation produces more twice the risk of MVA as controls. OR of Risk for MVA is dose dependent on the level of THC. When blood THC concentration was 5 ng/mL, the OR for MVA increased to 6.6—similar to that of a 0.15% blood alcohol concentration (BAC). Study of 456 Norwegian suspected impaired drivers showed a mean of 2 ng/mL THC but assessment showed 54% of drivers were impaired. Review of specific skill tests that THC use impaired presented. Discussion on synergism of EtOH and marijuana. |

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Table A2. (continued)

| Author (Year), Title, Journal  | Study Type                             | Summary of Findings  |
|--|--|--|
| Iversen (2003), Cannabis and the brain. <i>Brain</i> .   | Review                                 | Examines pathophysiology of cannabinoid receptors in CNS and effects of endogenous and exogenous sources. Reviews literature supporting chronic effect of chronic THC on cognition. No direct relevance to acute impairment in driving.  |
| Kalant (2004), Adverse effects of THC on health. <i>Prog Neuro-Psychopharmacol Biological Psych</i> .  | Review                                 | Discusses difficulty in obtaining serum testing as practical test for THC. Cites a number of case-control studies that imply an association to the increase in car accidents with TCH use. Also looks at literature for more chronic disease and mental health problems associated with marijuana use.                   |
| Kelly (2004), Review of drug use and driving. <i>Drug Alc Rev</i> .  | Review                                 | Comprehensive review article looks at the prevalence of drugs and driving, effects on driving performance, and risk factors associated with drug driving. Marijuana effects last for 4 h, which results in driving impairment in testing. Cited 3 studies that state that effects of THC are potentiated by EtOH.        |
| Kuypers (2012), A case-control study estimating accident risk for alcohol, medicines and illegal drugs. <i>PLOS One</i>  | Population-based case-controlled study | Samples obtained from 337 injured drivers sent to hospital. Drug levels compared to 2726 control drivers randomly selected by police in the same geographic area. OR for significant difference in accidents with THC detectable is 6 for 1 to 2 ng/mL THC and 24.83 for 2 to 5 ng/mL (13 OR overall for marijuana use). |
| Leirer (1991), Marijuana carry-over effects on pilot performance. <i>Aviat Space Env Med</i> .   | Cohort study                           | Too specific a test population (9 currently active pilots) to be relevant to general population.   |
| Longo (2000), The prevalence of alcohol, cannabinoids, benzodiazepines and stimulants amongst injured drivers and their role in driver culpability. <i>Accid Anal Prev</i> | Retrospective population-based study   | Population study looked at prevalence rate of drug use in 2500 injured drivers. Of only indirect relevance.  |
| Musshoff (2006), Blood, urine levels of THC and impairment. <i>Ther Drug Monitor</i> .   | Review                                 | Good review of pharmacokinetics of THC and metabolites. THC levels are usually less than the limit of detection at 5 to 7 h, <0.5 ng/mL.   |
| O'Kane (2002) Cannabis and driving. <i>Emerg Med</i> .   | Review                                 | Impairment from marijuana use can persist greater than 5 h after inhalation after blood levels are < 2 ng/mL. Marijuana can significantly exacerbate driving impairment caused by EtOH.  |

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Table A2. (continued)

| Author (Year), Title, Journal   | Study Type                               | Summary of Findings   |
|---|--|---|
| Pope (2001) Neuropsychological performance in long-term cannabis users. <i>Arch Gen Psychiatry</i> .                              | Case-controlled study                    | Study of long-term cognitive effects of marijuana use—3 groups all 30 to 55 years: (1) 63 current heavy users who smoked daily and at least 5000 times lifetime at study entry; (2) 45 former heavy users who smoked at least 5000 times but <12 times in last 3 months; and (3) 72 controls who smoked ≤ 50 times lifetime. A 28-day washout monitored by observed urine samples. Authors concluded that “some cognitive deficits appear detectable at least 7 days after heavy cannabis use but appear reversible and related to recent cannabis exposure rather than irreversible and related to cumulative lifetime use.” Controls not matched—not directly addressed in the current paper. |
| Pope (2001), Residual neuropsychologic effects of cannabis. <i>Curr Psych Rep</i> .   | Review                                   | Literature review. Not relevant.  |
| Pope (1996), The residual cognitive effects of heavy marijuana use in college students. <i>JAMA</i> .                             | Single-blinded comparison study          | Two samples of college undergraduates: 65 heavy users smoked marijuana a median of 29 days in past 30 days (range, 22 to 30 days) and displayed cannabinoids in urine, and 64 light users, who smoked a median of 1 d in the last 30 d (range, 0 to 9 d) and displayed no urinary cannabinoids. The study found heavy use associated with residual neuropsychological effects even after a day of supervised abstinence. “However, the question remains open as to whether this impairment is due to a residue of drug in the brain, a withdrawal effect from the drug, or a frank neurotoxic effect of the drug.”  |
| Pope (1995), Residual effects of THC. <i>Drug Alc Depend</i> .  | Review                                   | Literature review comparing drug-administration studies in which known amounts of cannabis administered to volunteers, and naturalistic studies where heavy marijuana users tested after period of abstinence. Data support a “drug residue” effect on attention, psychomotor tasks, and short-term memory during 12- to 24-h period after use, “but evidence is as yet insufficient to support or refute either a more prolonged ‘drug residue’ effect, or a toxic effect on the central nervous system that persists even after drug residues have left the body.”  |
| Ramaekers (2009), Neurocognitive performance in acute THC intoxication. <i>J Psychopharm</i> .                                    | Double-blinded, placebo-controlled study | Low-quality study. Attempted to assess neurocognitive performance during acute THC intoxication in 24 subjects: 12 occasional users and 12 heavy users. Authors concluded that cannabis use history strongly determines behavioral response to a single dose of THC.  |
| Ramaekers (2009), Dose-related risk of motor vehicle crashes after cannabis use: an update. <i>Drugs Driving Traffic Safety</i> . | Review                                   | Updates 2004 review.  |

(continued)

Table A2. (continued)

| Author (Year), Title, Journal  | Study Type        | Summary of Findings   |
|--|-------------------|---|
| Ramaekers (2004), Dose-related risk of motor vehicle crashes after cannabis use. <i>Drug Alc Depend.</i>                                 | Review            | Review of effects of cannabis on performance and driving ability.   |
| Ramaekers (2002), Cannabis 2002 Report. <i>Ministry of Public Health Belgium.</i>  | Review            | Review of the literature to attempt to summarize/integrate what is known about effect of cannabis on performance and driving ability in particular. Focused on short- and long-term effects of THC on cognitive functioning as relevant to driving.   |
| Reeve (1983), Hemolyzed blood and serum levels of delta-9-THC: effects on performance of roadside sobriety tests. <i>J Forensic Sci.</i> | Pilot study       | Pilot study of 58 subjects and 69 blinded controls tested within 5 min of smoking marijuana cigarette (18-mg THC) and at 30-min intervals for 150 min. Subjects demonstrated a broad range of THC blood levels, which settled within 1 h. Subjective judgments of impairment exhibit adaptational effect.   |
| Reeve (1983), Plasma concentrations of delta-9-tetrahydro-cannabinol and impaired motor function. <i>Drug Alcohol Depend.</i>            | Pilot study       | Follow-up to the aforementioned study: 59 volunteers smoked marijuana cigarettes until satisfactory level of "high" obtained. Then blood samples taken 5, 30, 90, and 150 min following smoking after which tested with roadside ST. Overall, 94% of subjects failed to pass test 90 min after smoking and 60% after 150 min, despite the fact that by then plasma concentrations were rather low. Authors surmise that establishing a clear relation between THC plasma concentrations and clinical impairment will be much more difficult than it has been for alcohol.   |
| Robbe (1993), Marijuana and actual driving performance. <i>NHTSA.</i>  | Government report | Presents results of 1 pilot and 3 actual driving studies. Pilot study was to establish THC dose current marijuana users smoke to achieve desired "high." Report results found THC's adverse effects on driving performance appear relatively small.   |
| Sewell (2009), The effect of cannabis compared with alcohol on driving. <i>Am J Addict.</i>  | Review            | Three types of studies performed to assess risk of cannabis use and having fatal traffic accident. Cognitive studies show that attentiveness, vigilance, perception of time and speed, and use of acquired knowledge are all affected by THC. A meta-analysis of 60 studies concluded that marijuana impairs every performance area connected with safe driving. Marijuana and EtOH have additive or multiplicative effects on impairment. Experimental studies on driving skills or via simulator found that most THC-intoxicated drivers show only modest impairments on actual road tests, and experienced smokers show almost no <i>functional</i> impairment except when combined with EtOH. Maximal impairment 20 to 40 min after smoking, gone 2.5 h later in those who smoke 18-mg THC or less. |

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Table A2. (continued)

| Author (Year), Title, Journal   | Study Type        | Summary of Findings   |
|---|-------------------|---|
| Subbaraman (2014), Can cannabis be considered a medication for alcohol? <i>Alcohol Alcohol.</i>       | Literature review | Not applicable. Looked at whether cannabis should be prescribed for alcohol-dependent people to attempt to reduce alcohol intake.   |
| Verstraete (2011), Per se limits—methods of defining cut-off values for zero tolerance. <i>DRUID.</i> | Review            | Makes recommendations for establishing cutoff levels for drugs in <i>per se</i> legislation for DUI in European nations. THC half-life of 1.4 h (3 ng/mL of THC decreases to 0.68 ng/mL after 3 h). <i>Two-tiered approach: Per se</i> limits (for drugs with limits for zero tolerance) combined with an impairment approach. Generally, European countries use the limits of quantification of their official lab as <i>per se</i> limit for THC; those using two-tiered system use drug impairment level that equates to a 0.05 g% BAC impairment.   |
| Volkow (2014), Adverse health effects of marijuana use. <i>N Engl J Med.</i>                          | Review            | Immediate use and long-term exposure to marijuana impair driving ability; marijuana most frequently DUI substance reported; blood THC concentration is correlated with performance in controlled driving-simulators; recent marijuana use and blood THC levels of 2 to 5 ng/mL associated with substantial driving impairment. Risk of impairment doubles when driving soon after using marijuana; persons positive for THC (>1 ng/mL), especially those with higher blood levels, were 3 to 7 times more likely to be deemed culpable for an MVA than nonusers. Notes THC potency of marijuana steadily increasing; raises question whether older studies of impairment due to less potent THC cigarettes are still valid. |

BAC, blood alcohol concentration; CNS, central nervous system; DUI, driving under the influence; EtOH, ethyl alcohol; THC, delta-9-tetrahydrocannabinol.

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