

# Drugs and Traffic Crash Responsibility: A Study of Injured Motorists in Colorado

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**Background:** Alcohol is a contributing factor in a large proportion of traffic crashes. However, the role of other drugs is unknown. The objectives of this study are to determine the prevalence of recent drug use among drivers injured in traffic crashes, and to determine the extent to which drugs are responsible for crashes.

**Methods:** We studied 414 injured drivers who presented to an urban emergency department within 1 hour of their crash. Demographic and injury data were collected from medical records. Urine toxicologic assays were conducted for legal and illegal drugs. Traffic crash reports were analyzed for crash responsibility by a trained crash reconstructionist. The

causal role of drugs in traffic crashes was measured by comparing drug assay results in drivers judged responsible for their crashes (cases) and those not responsible (controls). Odds ratios and 95% confidence intervals (CIs) were calculated.

**Results:** Thirty-two percent (95% CI = 27-37) of the urine samples were positive for at least one potentially impairing drug. Marijuana was detected most frequently (17%), surpassing alcohol (14%). Compared with drug- and alcohol-free drivers, the odds of crash responsibility were higher in drivers testing positive for alcohol alone (odds ratio [OR] = 3.2, 95% CI = 1.1-9.4) and in drivers testing positive for alcohol in combination with other

drugs (OR = 3.5, 95% CI = 1.2-11.4). Marijuana alone was not associated with crash responsibility (OR = 1.1, 95% CI = 0.5-2.4). In a multivariate analysis, controlling for age, gender, seat belt use, and other confounding variables, only alcohol predicted crash responsibility.

**Conclusion:** Alcohol remains the dominant drug associated with injury-producing traffic crashes. Marijuana is often detected, but in the absence of alcohol, it is not associated with crash responsibility.

**Key Words:** Traffic safety, Injury prevention, Alcohol, Drugs, Crash responsibility.

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For more than a century, alcohol has been recognized as one of the principal risk factors for automobile crashes. However, relatively little attention has been paid to drugs other than alcohol.<sup>1</sup> Many prescription, proprietary, and illegal drugs affect the nervous system and have the potential to impair driving ability. Several drug classes, including barbiturates, sedative-hypnotics, antihistamines, and stimulants, have been shown to impair driving skill in laboratory tests and driver-simulation studies.<sup>2-13</sup> Therefore, it is often assumed that nonalcohol drugs pose major risks for traffic crashes and injuries.

Data to support this association are problematic or do not exist. Research in this area has been impeded by several

barriers. First, alcohol may not be a good model for other drugs that have different pharmacokinetic properties and biologic effects.<sup>9</sup> Little is known about the correlations that may exist between blood concentrations of drugs and driving impairment,<sup>1,2</sup> and positive drug tests do not always indicate recent drug use.<sup>1,14,15</sup>

Second, although many reports have demonstrated a high rate of drug use in motorists involved in fatal and injury-producing crashes,<sup>2,14-20</sup> few studies have collected comparable drug use data from comparison groups who are not involved in crashes.<sup>5,20-23</sup> The presence of a drug in an injured driver is not proof that the drug played a causal role in the crash.

Third, in many studies that purport to demonstrate an association between drug use and crash involvement, 40% to 80% of drivers testing positive for drugs are also intoxicated with alcohol.<sup>11,14,15,20,22</sup> In these studies, it is not possible to isolate the true cause of driving impairment.

Fourth, many studies do not address the biases caused by selective drug testing. For example, in one recent study only 58% of eligible, injured patients were approached and screened for drugs, raising questions about selection bias.<sup>24</sup>

Finally, the studies reported until now have seldom considered confounding variables that may have an association with drug use and an independent effect on crash involvement or the occurrence of an injury. These variables include driver age and sex, time of day, vehicle speed, concomitant alcohol intoxication, and seat belt use.<sup>25</sup> It could even be argued that drug use does not cause substantial impairment of driving

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skills but is only a marker for other injury-prone traits, such as impulsiveness, risk-taking, or aggressive driving.

Nevertheless, despite the paucity of controlled studies, there are reasons to be concerned about the problem of drugged driving. The use of illegal drugs, especially cocaine and marijuana, remains prevalent. In 1998, an estimated 13.6 million Americans (6.2% of the U.S. population ages 12 years and older) used marijuana, cocaine, hallucinogens, or other illicit drugs.<sup>26</sup> These drugs, along with prescription and over-the-counter medications, can affect motor skills, attentiveness, judgment, and reaction time, and all have the ability to degrade driving skills.<sup>2-13,20,23</sup> In one study in New York City, recent cocaine use was detected at autopsy in 20% of drivers killed in traffic crashes; among drivers 16 to 45 years of age, 25% had used cocaine within 48 hours of their death.<sup>14</sup>

Surveys also show that cocaine and marijuana users often drive while, or shortly after, using these drugs. In a national survey, 46% of marijuana users reported driving within 3 hours of marijuana use one or more times in the preceding year. A similar proportion (43%) of cocaine users reported driving within 1 hour of using cocaine.<sup>27</sup>

Although drug use remains an important theoretical risk for motor vehicle crashes, the true extent of the problem is unknown. In the current study, we investigated the relationship between drug use and traffic crash responsibility. Our study had two main objectives: first, to measure the prevalence of alcohol and drug use in a sample of drivers injured in traffic crashes; and second, to determine the degree to which drugs were responsible for the crashes.

## **MATERIALS AND METHODS**

### **Design and Setting**

We studied a sample of injured drivers presenting to the emergency department (ED) at the University of Colorado Hospital in Denver, Colorado. The hospital is a Level II trauma center that serves the Denver metropolitan area. The study was approved by the combined institutional review board of the University of Colorado.

This case-control investigation used "responsibility analysis," a technique in which each driver is rated as "responsible" or "not responsible" for his or her crash. Crash-responsible drivers (cases) are then compared with nonresponsible drivers (controls).<sup>15,22,28,29,39</sup> If drugs are causally related to crashes, drug screens should be positive more often in the cases—those drivers who are judged "responsible" for their crash.

### **Patient Entry**

Patients were eligible for study entry if they met each of the following criteria: they were a driver of a passenger car, motorcycle, van, or truck; they arrived at the ED within 1 hour of the crash; and they were age 18 years or older. All injured drivers were eligible, regardless of crash or injury severity. Patient enrollment began in June 1995 and contin-

ued until a target of 400 injured drivers was achieved. The enrollment target was determined on the basis of the sample size needed to provide an adequate level of precision in estimating drug use (95% confidence limits of  $\pm 4\%$ ) and to detect a difference in crash responsibility of 20% or greater between drug-positive and drug-free drivers ( $\alpha = 0.05$ ;  $\beta = 0.20$ ; estimated case-to-control ratio = 1:4).

### **Case-Control Assignment**

To determine crash responsibility, the methods of Williams et al.,<sup>15</sup> Robertson and Drummer,<sup>29</sup> Terhune et al.,<sup>22</sup> Terhune,<sup>28</sup> and Mounce and Pendleton<sup>39</sup> were used. Crash responsibility was assigned to drivers on the basis of several precrash variables, including speed, direction of travel, number of vehicles, and traffic violations and other improper driving acts. Responsibility analysis also takes into account external mitigating factors, such as poor lighting or visibility, adverse weather or road conditions, or other circumstances unfavorable to driving.

Crash data were obtained from the Colorado Investigator's Traffic Accident Report, completed by police officers at the scene. These reports include an accident description, collision diagram, list of driver actions, statements of witnesses, citations, descriptions of weather, lighting and roadway conditions, and an opinion by the investigating officer regarding the at-fault driver.<sup>38</sup>

Crash responsibility was assigned by an experienced traffic crash reconstructionist, who reviewed each Traffic Accident Report. The reconstructionist was blinded to all information pertaining to alcohol or drug use, including citations. The crash reconstructionist also had no knowledge of the driver's clinical data or toxicology results. The reconstructionist was asked, "Considering driver behavior, road conditions and the like, please rate the driver on a scale from 1 (fully responsible) to 4 (not at all responsible)." Drivers who were assigned any degree of crash responsibility were considered to be cases; drivers who were fully exonerated (judged "not at all responsible") served as controls.

To test the validity of case assignment, the reconstructionist was also asked to complete the quantitative Robertson and Drummer crash responsibility instrument.<sup>29</sup> The instrument was modified to improve clarity and to ensure consistency with data collected on the Colorado Traffic Accident Report. For each crash, eight mitigating factors (including environmental variables such as poor lighting or adverse weather conditions) and driver-related variables such as speed and driving acts, were weighted and scored. The total points possible ranged from 8 to 28, with higher scores reflecting additional mitigating circumstances, exonerating the drivers from crash responsibility.

In this study, the quantitative responsibility scores and the qualitative assignment of responsibility were strongly correlated ( $r = 0.82$ ). In addition, the intrarater reliability of the responsibility analysis was tested in a random sample of 24 crash records. The crash reconstructionist rescored each

**Table 1** Drug Categories and Rates of Positive Drug Tests (n = 414)

Major drug Categories	Screening Procedure	Threshold Limit	No.	Percentage Positive (%)	95% CI
Alcohol	Enzymatic	0.04 %	57	14	10.6–17.4
Marijuana	EIA/FPIA	25 ng/mL	70	17	13.4–20.9
CNS stimulants					
Cocaine	EIA	300 ng/mL	15	4	2.0–5.9
Amphetamines	EIA	1,000 ng/mL	3	< 1	0.2–2.1
Narcotic analgesics					
Opiates	EIA	300 ng/mL	6	1	0.5–3.1
Propoxyphene	EIA	300 ng/mL	6	1	0.5–3.1
Methadone	EIA	300 ng/mL	1	< 1	.01–1.3
CNS depressants					
Benzodiazepines	EIA	200 ng/mL	5	1	0.4–2.8
Meprobamate	EIA	200 ng/mL	2	< 1	0.1–1.7
Barbiturates	TLC	300 ng/mL	4	1	0.3–2.5
Phencyclidine	EIA	75 ng/mL	0	0	
Hallucinogens (LSD)	RIA	0.5 ng/mL	0	0	
Toxic vapors					
Xylene	GC	Various	3	< 1	0.2–2.1

EIA, enzyme immunoassay; FPIA, fluorescence polarization immunoassays; RIA, radioimmunoassay; TLC, thin layer chromatography; GC, gas chromatography; LSO, lysergic acid diethylamide.

record, without knowledge of prior scoring. Intrarater reliability was excellent for both the qualitative analysis (weighted  $\kappa = 0.97$ ) and for the quantitative responsibility score (intraclass correlation coefficient = 0.94).

## Drug Exposure

A urine sample was requested from each injured, eligible driver. Urine samples were analyzed by the toxicology laboratory of the Colorado Department of Public Health and Environment. The toxicology laboratory participates in quality control and proficiency testing and is licensed under the Clinical Laboratories Improvement Act of 1967. Various procedures (enzyme immunoassays, fluorescence polarization immunoassays, radioimmunoassays, thin layer chromatography, gas chromatography, and gas chromatography/mass spectrometry) were used to detect the presence of drugs.<sup>37</sup> All positive tests were followed by confirmatory testing.

Drugs were classified into eight categories (Table 1). The drugs in this list have been identified by the American Academy of Forensic Scientists<sup>2</sup> and by the National Highway Traffic Safety Administration<sup>20,33</sup> as those most likely to impair driving and to be detected in fatality- or injury-producing crashes. This list also includes the most prevalent drugs of abuse in Colorado<sup>34</sup> and the drugs most frequently detected among impaired Colorado motorists.<sup>35,36</sup>

The injured motorists were classified, according to their drug test results, into one of five groups: drug- and alcohol-free; positive for alcohol alone; positive for nonalcohol drugs alone; positive for marijuana alone; or positive for drugs in combination with alcohol.

## Secondary Marijuana Testing

Marijuana (metabolites of cannabinol) may be detected in the urine for extended periods (hours or days) after inhalation. To differentiate between recent and nonrecent marijuana use, we conducted secondary marijuana testing using a new liquid-liquid extraction procedure that tests for the parent drug ( $\delta$ -9-tetrahydrocannabinol [THC]) and the psychoactive metabolite (11-OH-THC).<sup>40–42</sup> These assays, not available at the state toxicology laboratory until after the completion of the study, were performed on thawed urine samples that had originally tested positive for marijuana. The cutoff level for both cannabinoids was 5 ng. Drivers were categorized as follows: *acute marijuana use* ( $\delta$ -9-THC positive, indicating marijuana inhalation within several hours); *recent marijuana use* (11-OH-THC positive, indicating use within approximately 30 hours); or, *remote marijuana use* (COOH-THC).

## Covariates: Clinical and Demographic Data

Clinical and demographic information was obtained from the medical records by trained chart abstractors, using a standardized data collection form. Age, gender, time of ED arrival, day of the week, reported seat belt use, vital signs, Glasgow Coma Scale score, and ED disposition were noted for all patients. An experienced trauma nurse coordinator reviewed each medical record and calculated the Abbreviated Injury Scores, Injury Severity Scores (ISSs) and the Revised Trauma Scores.<sup>30–32</sup> Missing data on individual variables ranged from 2% to 6%.

## Data Analysis

Some eligible patients could not be enrolled in the study because of logistic barriers or staffing shortages. To test for missing case bias, we compared the patients who were en-

rolled with a systematic sample of every fifth missed patient. Demographic characteristics of the drivers, crash variables (e.g., vehicle type, crash mechanism, speed, and time of day), and injury severity were compared. To test for statistical significance, we used the  $\chi^2$  test for categorical variables, Student's *t* test for measurement variables, and the Wilcoxon rank sum test for measurement data with a nonnormal distribution.

To measure the prevalence of alcohol and drug use, we calculated drug prevalence rates and 95% confidence intervals (CIs) for the eight drug categories tested. We tested for associations between drug use and driver age, gender, seat belt use, and other vehicle and crash characteristics, using the tests of statistical significance listed above.

To measure associations between drug use and crash responsibility, we compared the rates of drug and alcohol detection in crash-responsible drivers (cases) and nonresponsible drivers (controls). We calculated odds ratios (ORs) and 95% CIs. Multiple logistic regression modeling was used to examine the association between drugs and crash responsibility, after controlling for other driver and crash variables. Adjusted ORs and 95% CIs were calculated.

## RESULTS

### Patient Entry

During the 1-year enrollment period (June 15, 1995, to June 13, 1996), there were 652 eligible, injured drivers identified. Of these, 414 (64%) were entered into the study. There were no differences between the 414 patients who were entered into the study and the 238 patients who were missed with regard to any driver or ED characteristic (driver age, gender, time of visit, mode of arrival, vehicle type, restraint use, proportion admitted to the hospital, or proportion with severe injuries [ISS  $\geq$  16]). Entered and missed patients also did not differ in crash characteristics, including roadway type, number of vehicles (single vs. multiple vehicle), weather conditions, or extent of vehicle damage. There were also no differences in qualitative or quantitative crash responsibility scores between entered and missed patients.

The 238 "missed" patients could not be entered into the study because no urine samples were submitted for toxicologic analysis. In most cases, urine samples were not submitted because there was no apparent injury, the patient was unable to urinate, the urine sample was too small, or the staff was too busy. Posters, reminders, and staff education activities helped to increase the patient entry rate over the course of the study from 54% in the first quarter to 69% in the final quarter. There were no patient "refusals," because the study did not require patient consent, patient interviews, or any other active patient participation.

### Driver and Emergency Visit Characteristics

Most drivers were involved in passenger car or truck crashes (95%), were transported to the ED by ambulance or air transport (94%), and arrived at the ED during the day or

**Table 2** Assignment of Crash Responsibility (n = 368)<sup>a</sup>

Qualitative Assignment	Number	Percentage (%)
1 (fully responsible)	153	41.8
2	24	6.6
3	9	2.4
4 (fully exonerated)	180	49.2

<sup>a</sup> Responsibility analysis was not possible in five cases because of incomplete crash records.

evening hours (89%). Only a small proportion of patients had severe injuries: 1% had evidence of significant neurologic impairment (Glasgow Coma Scale score  $\leq$  8), and 2% had ISS scores  $\geq$  16, indicating a moderate or severe injury.

### Crash Characteristics

Three hundred seventy-one crash records, representing 90% of the 414 entered patients, were retrieved from the Colorado Motor Vehicle Division and were analyzed by the accident reconstructionist. Forty-three crash records were missing, most often because of differences in spelling of drivers' names or because the crash was not reported. Crashes generally occurred on divided roadways (65%) during clear, daylight conditions (66%). Eighty-five percent of crashes involved multiple vehicles.

### Crash Responsibility

The Traffic Accident Reports provided sufficient information to judge responsibility in all but five cases; 91% of drivers were classified as completely responsible or completely exonerated (Table 2). Thus, the sample included 186 cases (drivers assigned complete or partial responsibility for the crash) and 180 controls (drivers with no crash responsibility).

There were no associations between crash responsibility and any of the following driver or crash characteristics: driver age, gender, type of vehicle (motorcycle vs. car or truck), type of roadway, or driving conditions. The only variable that was associated with crash responsibility was the number of involved vehicles: 95% of drivers in single-vehicle crashes were judged responsible, compared with 43% of drivers in multiple vehicle crashes ( $p < 0.01$ ).

### Rates of Alcohol and Drug Use

Among the 414 enrolled, injured drivers, 132 (32%; 95% CI = 27.4-36.6) were positive for at least one category of drug. Most of the drivers with positive drug tests were positive for a single drug (22% of all drivers); some drivers tested positive for two drugs (8.5%), three drugs (1.4%), or four drugs (0.2%).

The detection rates for each of the principal drug groups are listed in Table 1. Marijuana was found most frequently (17%), surpassing even alcohol (14%). Fifteen drivers (4%) tested positive for cocaine metabolites. Of these, six had detectable cocaine, indicating recent use. Cocaethylene, a



**Table 3** Odds of Crash Responsibility by Drug Exposure<sup>a</sup>

	Number	Percentage Responsible (%)	Odds Ratio	95% CI
Drug-free (comparison drivers) <sup>b</sup>	240	47.5	—	—
Alcohol alone	23	73.9	3.2	1.1–9.4
Nonalcohol drugs <sup>c</sup>	67	50.8	1.2	0.7–2.1
Marijuana alone	34	50.0	1.1	0.5–2.4
Alcohol + nonalcohol drug(s) <sup>c</sup>	21	76.2	3.5	1.2–11.4

<sup>a</sup> Persons may be in one or more “drug positive” category.

<sup>b</sup> No drugs (illicit, prescription, or over-the-counter) were detected.

<sup>c</sup> Non-alcohol drugs included one or more of the following: marijuana, CNS stimulants, narcotic analgesics, phencyclidine, hallucinogens, or toxic vapors (see Table 1).

potentially toxic combination of alcohol and cocaine, was found in three drivers.

Among the 70 subjects who tested positive for marijuana, 40 (57%) were positive for marijuana alone. The combination of marijuana and alcohol accounted for an additional 20%. Among the 57 patients testing positive for alcohol, 31 (54%) were positive for alcohol alone.

Secondary marijuana analysis was completed for 57 of the 70 marijuana-positive drivers (in the remaining cases, there was not enough urine for testing). Among the 57 samples tested, 10 (17.5%) were positive for acute marijuana use, 38 (67%) were positive for recent marijuana use, and the remaining 9 (16%) were positive for remote marijuana use. Caffeine was detected in two thirds (67%) of all drivers, and nicotine was detected in 35%. Diphenhydramine (3%), pseudoephedrine (1%), ephedrine (4%), and chlorpheniramine (<1%) were found in only a few cases.

### Associations between Positive Drug Screens and Driver and Crash Characteristics

Positive drug screens (excluding alcohol) were more common in motorcyclists (53%) compared with operators of cars or trucks (20%,  $p < 0.01$ ). Nonalcohol drugs were also found more often in drivers who were unrestrained or unhelmeted (50%) rather than restrained (24%,  $p < 0.01$ ) and who were involved in single-vehicle (32%) versus multiple vehicle (20%) crashes ( $p < 0.01$ ). Drivers who tested positive for drugs were also younger than those who tested negative (mean age  $\pm$  SEM = 34  $\pm$  12 vs. 39  $\pm$  17 years,  $p = 0.01$ ).

### Associations between Drugs and Crash Responsibility

We tested for associations between positive drug screens and crash responsibility. In each analysis, the comparison group was the cohort of drivers who tested negative for alcohol and all illicit, prescription, and over-the-counter medications. There were 267 drivers who were negative for all drugs. Of these, 240 had complete accident reports available for responsibility analysis. Among drivers in the “no alcohol or drug” group, 47% were judged responsible for their crash. This responsibility rate (47%) served as the rate to which each of the drug-positive groups was compared.

As shown in Table 3, drivers who tested positive for

alcohol alone were 3.2 times (95% CI = 1.1-9.4) more likely to be responsible for their crash, compared with drivers with no detectable alcohol or drugs. Drivers who tested positive for alcohol in combination with one or more other drugs were 3.5 times (95% CI = 1.2-11.4) more likely to be responsible for their crash, compared with drivers who were free of alcohol and drugs. In contrast, there was no significant association between a positive nonalcohol drug screen and crash responsibility. When marijuana was analyzed as a single drug category, no significant association was found between a positive test and crash responsibility. There were no associations between crash responsibility and acute marijuana use (OR = 0.7, 95% CI = 0.1-3.3), recent marijuana use (OR = 0.8, 95% CI = 0.3-2.0) or “any” (acute, recent, or remote) marijuana use (OR = 1.1, 95% CI = 0.5-2.4).

Multiple logistic regression was used to examine the contribution of drugs and alcohol to crash responsibility, while controlling for other driver and crash characteristics. In addition to alcohol and marijuana, age, gender, occupant restraint use, injury severity, and time of day were entered as independent variables. The sole independent predictor of crash responsibility was the presence of alcohol (adjusted OR = 2.6; 95% CI = 1.1-6.1). To examine the joint effects of alcohol and marijuana on crash responsibility, we performed a multiple logistic regression analysis that included the alcohol\*marijuana interaction term. The interaction was nonsignificant.

### DISCUSSION

This study provides new data about the role of alcohol and other drugs in injury-producing traffic crashes. It demonstrates that marijuana and alcohol are often present in drivers injured in traffic crashes. In fact, marijuana was detected more frequently than alcohol. In contrast, cocaine, amphetamines, opiates, central nervous system depressants, and hallucinogens were seldom found.

This study also verifies the well-known association between alcohol and crash responsibility. Drivers testing positive for alcohol alone were more than three times as likely to be responsible for their crash, compared with alcohol- and drug-free drivers. A strong association with crash responsibility was also found when alcohol was combined with other

drugs: drivers testing positive for alcohol in combination with one or more other drugs were 3.5 times more likely to be responsible for their crash. Alcohol was also the only variable that was associated with crash responsibility in the multivariate analyses, after controlling for driver, vehicle, and crash characteristics. Indeed, whenever it was present, alcohol strongly and significantly raised the odds of crash responsibility.

The association between nonalcohol drugs and crash responsibility was weak and statistically insignificant. For example, marijuana was the most common drug detected in injured drivers, but it was not associated with crash responsibility. This lack of association persisted even when only recent marijuana use was considered.

Our findings are similar to those of Terhune et al., who studied 1,882 fatally injured drivers in seven states.<sup>22</sup> In that study, alcohol was detected in 51.5% of drivers, and other drugs were detected in 17.8%. When Terhune et al. used the technique of responsibility analysis to “measure impairment effects,” such effects were found only for alcohol and for alcohol/drug combinations.

Similar results were reported by Waller et al., who studied 894 patients injured in motor vehicle crashes. Alcohol was associated with more severe crashes and greater injury; in contrast, there was no evidence that illicit drugs, including marijuana, opiates, or cocaine, increased crash or injury severity.<sup>43</sup>

Our findings are also consistent with those of Robbe et al., who found that, whereas impairment in test subjects’ driving skills was evident after THC, THC’s effects on driving were small, because subjects compensated for the impairment by slowing down or increasing effort.<sup>44</sup> Peck et al.<sup>45</sup> and Smiley et al.<sup>46</sup> have also found, using driver simulators, that subjects drive more slowly and conservatively after smoking marijuana. One study even found that marijuana use resulted in enhanced driving ability, possibly because users tended to overcompensate for the drug’s effects.<sup>47</sup>

Recently, Robbe and O’Hanlon studied the effects of alcohol, marijuana, and the two drugs combined in a natural traffic setting.<sup>23</sup> Eighteen young subjects (20–28 years of age) received marijuana, alcohol, marijuana plus alcohol, or placebo in a six-way crossover, double-blinded trial. The dose of alcohol was “moderate,” only enough to raise the mean blood alcohol concentration to about 0.04 g/dL. Four driving tests were performed, measuring lane changes, car following, and tracking errors. Minor impairment of driving ability was observed after alcohol, and minor to moderate impairment was observed after marijuana. Marijuana in combination with alcohol led to severe driving impairment, enough to “increase exponentially” the risk of driving off the road. Thus, several studies indicate an additive, or possibly synergistic, effect when alcohol and marijuana are combined. Robbe and O’Hanlon concluded that alcohol, in blood concentrations around the legal limit (0.10 g/dL in most American states), is more impairing than anything subjects have

shown after THC alone. However, these investigators warned that “subjects’ reactions to combined use of alcohol and THC are another matter. . . . Their impairment could be exceedingly dangerous [and] a serious threat to their own safety and perhaps to the general driving public as well.”<sup>23</sup>

Several significant limitations of the current study should be emphasized. First, the toxicologic assays permitted us to detect the presence of drugs, but not their levels. Furthermore, the methods of responsibility analysis can suggest, but not directly prove, driver impairment.<sup>22</sup> In addition, before testing the urine samples for active marijuana, the samples were frozen for up to 1 year. The freezing and thawing processes may have led to some degradation of marijuana and possibly to an *underestimation* of the prevalence of acute and recent marijuana use.

In addition, our study sample included predominantly middle-aged drivers with minor or moderate injuries. Rural drivers, teens, and severely injured drivers were not well represented. The study sample was also drawn exclusively from drivers injured in the Denver metropolitan area. Had drivers from other regions of the nation been included, other drugs (e.g., methamphetamine) might have been found more frequently.

The precision of our odds ratios decreased as we examined more specific, and therefore smaller, subgroups. For example, the confidence interval surrounding the odds ratio for acute marijuana use and crash responsibility was wide (0.1–3.3). In addition, we were unable to test for any effects on crash responsibility for opiates, anxiolytics, sedatives, amphetamines, or other drugs, because these drugs were detected at such low prevalence rates.

Most importantly, we used the only accessible group—crash-involved, but “nonresponsible,” drivers—as our control group. Some of the drivers that were judged “not responsible” may, in fact, have borne some responsibility, since they failed to avoid the crash. The ideal comparison group would consist of drivers who were not involved in crashes but who were on the road under similar circumstances of time and place.

## CONCLUSION

Four hundred fourteen drivers injured in traffic crashes were studied to determine the detection rates of alcohol and other drugs and to determine their causal role, if any, in these crashes. Alcohol was detected in 14% of injured drivers, and marijuana was found in 17%. Other drugs, including cocaine, amphetamines, sedative-hypnotics, narcotic analgesics, and other prescription and illegal drugs, were seldom detected. Crash responsibility analysis was used to test for the effects of driver impairment by drugs and alcohol. Alcohol and the combination of alcohol and marijuana were associated with crash responsibility. The odds of crash responsibility were not elevated by marijuana alone. In a multivariate analysis, controlling for age, gender, seat belt use, and other potentially confounding variables, alcohol was the sole significant and independent predictor of crash responsibility. Alcohol re-

mains the principal drug associated with traffic crash responsibility. Additional studies of nonalcohol drugs are needed to define the magnitude of the problem, if any, and the specific substances that should be of concern.

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