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The Impact of Cannabis on Driving

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ABSTRACT

Background: Cannabis is known to have detrimental effects on human performance and may also affect driving adversely. However, studies designed to examine this issue have provided equivocal findings. We set up this study to further determine the effect of cannabis on driving.

Methods: We used a cross-sectional, case-control design with drivers aged 20-49 who were involved in a fatal crash in the United States from 1993 to 2003; drivers were included if they had been tested for the presence of cannabis and had a confirmed blood alcohol concentration of zero. Cases were drivers who had at least one potentially unsafe driving action recorded in relation to the crash (e.g., speeding); controls were drivers who had no such driving action recorded. We calculated the crude and adjusted odds ratios (ORs) of any potentially unsafe driving action in drivers who tested positive for cannabis but negative for alcohol consumption. In computing for the adjusted OR, we controlled for age, sex, and prior driving record.

Results: Five percent of drivers tested positive for cannabis. The crude OR of a potentially unsafe action was 1.39 (99% CI = 1.21-1.59) for drivers who tested positive for cannabis. Even after controlling for age, sex, and prior driving record, the presence of cannabis remained associated with a higher risk of a potentially unsafe driving action (1.29, 99% CI = 1.11-1.50).

Conclusion: Cannabis had a negative effect on driving, as would be predicted from human performance studies. This finding supports the need for interventions to decrease the prevalence of driving under the influence of cannabis, and indicates that further studies should be conducted to investigate the dose-response relationship between cannabis and safe driving.

MeSH terms: Cannabis; accidents; traffic; alcohol drinking; automobiles

La traduction du résumé se trouve à la fin de l'article.

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A survey revealed that 7.3% of Canadians used cannabis (marijuana) at least once in the previous year and that 2.0% used it weekly.¹ Similarly, American (US) surveys revealed that the prevalence of cannabis use in the previous year is approximately 4%.² However, cannabis use is more prevalent among young people. Among Canadian undergraduate students, 18.2% reported using cannabis during the academic year.³ In the US, the prevalence of past-year use among adults aged 18-29 in 2000-01 was 10.5%. In a survey of US college students, 15.7% reported having used cannabis in the past 30 days.⁴ While these trends fuel many debates about cannabis use, one persistent unresolved issue is the potential effect of cannabis on driving.⁵

The effect of cannabis on the human system is wide-ranging, combining "...many of the properties of alcohol, tranquilizers, opiates and hallucinogens; it is anxiolytic, sedative, analgesic, psychedelic; it stimulates appetite and has many systemic effects."⁶ (p. 103-104) Nonetheless, while the negative effect of cannabis on cognitive functions supporting safe driving was documented by some researchers,⁷⁻⁹ others¹⁰ have reported that performance is affected minimally, and often only in conjunction with alcohol. Epidemiological studies also provide equivocal findings. Some have demonstrated a small but statistically significant association between cannabis use and driving problems.¹¹⁻¹³ However, many researchers have not found an association between cannabis use and crashes (see refs. 14 and 15 for reviews).

It is possible that cannabis has minimal effects because drivers compensate for their impairment.⁵ However, it is also possible that methodological issues explain discrepancies in these findings. The concentration of THC (the active ingredient in cannabis) in drivers is typically not available nor is the amount of time since it was absorbed. Recently absorbed cannabis may affect driving adversely but this effect may wane once a longer period of time has elapsed after absorption.¹⁶ Because THC has a half-life of approximately seven days,⁶ many drivers who test positive for cannabis may not be impaired at the time of testing. This would lead to an underestimation of the association between cannabis and poor driving/crashes and possibly the absence of

statistical significance. Furthermore, because the prevalence of cannabis use is relatively low in the general population, small sample sizes yield limited numbers of users involved in crashes.¹⁷ One remedy to this problem is to use large datasets. Although these would not eliminate the underestimation of the association, a greater number of cases would increase the statistical power of the analyses.

Another problem is that cannabis use is often highly correlated with other crash determinants (e.g., alcohol use, high-risk behaviour). Alcohol use is especially problematic given that it is correlated with crashes, and that it may exacerbate the effects of cannabis.¹⁶ Other high-risk behaviours such as speeding, may also confound the association between cannabis and crashes. Drummer and colleagues¹⁸ reported an association between THC and responsibility for crashes (OR = 2.7, 95% CI = 1.0-7.0) but could not take into consideration high-risk behaviours (with the exception of alcohol use). Hence, the possibility remains that cannabis users are simply high-risk drivers who are involved in a disproportionate number of crashes; this requires that we separate the respective effects of cannabis and alcohol, and control for high-risk driving habits.

Another methodological problem is the reliance on self-reports to identify cannabis use and crashes.¹³ Given the social and legal implications of cannabis use, self-reports may also result in the underestimation of the association between cannabis and crashes. Ideally, the presence of THC in the body and crash status should be determined through objective means (e.g., blood tests, police reports).

Our goal was to clarify the association between cannabis use and driver behaviour. Specifically, we aimed to determine if cannabis, in the absence of alcohol, is related to driving actions that may have resulted in fatal crashes. We used the Fatality Analysis Reporting System (FARS), an administrative database where information on all crashes involving a fatality in the US is recorded. This database has several advantages. First, all crashes involving at least one fatality are included, therefore reducing selection bias. Second, the information is obtained by investigators, therefore eliminating biases that may arise from self-reports. Third, it contains actual blood

TABLE I**Descriptive Statistics for Drivers Involved in Fatal Automobile Collision**

Demographics (N=314,636)	
Age, mean (SD)	32.48 (8.59)
Male, No. (%)	222,671 (71)
Driving Record – Any in the Past Three Years (N=314,636)	No. (%)
Crashes	50,430 (16)
DWI	15,873 (05)
Other conviction	59,983 (19)
Speeding	79,000 (26)
License suspension/revocation	52,171 (17)
Any of the above	153,240 (49)

TABLE II**Odds Ratios and Confidence Intervals of a DRF by BAC**

BAC Level	Model 1 – Unadjusted Odds Ratio (95% CI; 99% CI)	Model 2 – Adjusted Odds Ratio (95% CI; 99% CI)
0	Reference category	Reference category
0.05	2.20 (2.08-2.32; 2.05-2.36)	2.01 (1.90-2.13; 1.87-2.16)
0.10	3.37 (3.21-3.54; 3.17-3.59)	3.06 (2.91-3.22; 2.87-3.27)
0.15	4.73 (4.52-4.94; 4.46-5.01)	4.40 (4.20-4.61; 4.14-4.68)
0.20	5.74 (5.50-5.98; 5.43-6.06)	5.61 (5.36-5.86; 5.29-5.95)
0.30	6.00 (5.69-6.33; 5.59-6.44)	6.16 (5.82-6.52; 5.71-6.64)

alcohol concentration (BAC). Fourth, it contains information on prior driving incidents (e.g., crashes, violations) to control for high-risk driving behaviours. Finally, it is sufficiently large to allow us to focus only on drivers who were tested for drugs and alcohol, and to examine the drivers' actions that may have resulted in the crash. Based on previous research and the acknowledged impact of cannabis on cognitive functions, we hypothesized that cannabis use would be related to poorer driver behaviour.

METHODS**Data source**

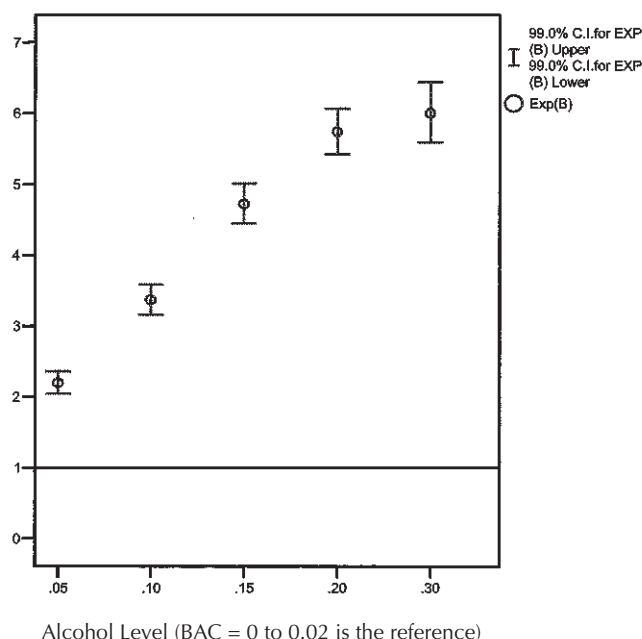
The FARS database is one of the most comprehensive databases on crashes.¹⁹ For every traffic fatality in the US since 1975, information is compiled about crash situations, drivers and passengers, and about the vehicles involved. The quantity of information coded in the database, and number of crashes recorded, allows for the control of numerous potential confounders, and the calculation of crash estimates more easily generalized to all drivers involved in fatal crashes.²⁰

We used data from 1993 to 2003 (inclusive) because drug information has been collected more comprehensively since 1993. The database also contains information to identify risk factors pertinent to crash initiation and not only crash involvement. This information is contained in the "driver-related factors" (DRF). Briefly, for

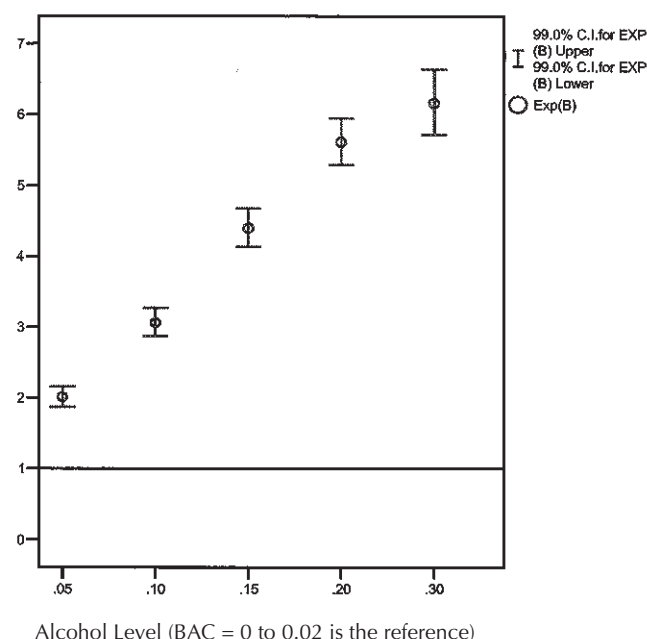
every driver, up to three (four since 1997) driver-related factors were coded according to police reports. Driver-related codes from 20 to 59 (inclusive) were considered actions that may have contributed to the crash (e.g., driving too fast for the conditions; these codes are presented in the Appendix). Drivers for whom no DRFs were specified were assumed to not have contributed to crash initiation. This approach is not a perfect substitute for the assessment of "responsibility" but has been used successfully by other researchers.²¹⁻²³ Our aim was to identify predictors of any DRF.

We used other data from FARS, including: age, sex, drug test results (blood or urine), alcohol tests results (blood), drivers' past driving record, and the type of vehicle driven. For each driver, a maximum of three drug results were provided (in no particular order). The cannabinoid drug compounds (FARS 600 series) were included: Delta 9 (600), Hashish Oil (601), Hashish (602), Marijuana (603), Marinol (604), Tetrahydrocannabinoid (605), THC (606), Cannabinoid, Type Unknown (695); the concentration of the drug is not available. For alcohol, the actual BAC is available. This allowed us to identify drivers who were tested for alcohol use, to verify the validity of our approach with alcohol data, and to examine the contribution of cannabis in drivers free of alcohol. We elected to use only drivers for whom both alcohol and drug tests were performed and reported because one

Panel A: Unadjusted Odds Ratios



Panel B: Adjusted Odds Ratios

**Figure 1.** OR and 99% CI for any DRF by BAC (categorical) level

potential bias is that only drivers suspected of impairment may be tested.

We also used data on drivers' past three years' driving record, including: number of accidents (crashes), number of recorded convictions for driving while impaired (DWI; includes both alcohol and drug), speeding convictions (going too fast *or* too slow), other harmful moving violation convictions, and licence suspensions and revocations. Because controlling for driving habits through these variables is important to rule out the confounding effect of high-risk driving habits, we excluded drivers aged less than 20 because they may not have had sufficient opportunity (years) to incur such records. We excluded drivers aged 50 and over because cannabis use becomes much less frequent with advancing age. Finally, we limited our analyses to drivers of passenger vehicles, sport-utility vehicles and light trucks (pick-up trucks) only. The focus on these drivers will facilitate the interpretation of the findings.

Analytical plan

We first sought to confirm known findings regarding alcohol use and crashes by demonstrating a dose-response relationship between BAC and DRF. To this effect, we used two logistic regressions using the report of any DRF as the dependent variable. In the first model, the only predictor

variable was BAC coded as the following categories: 0 (0-0.02; the reference category), 0.05 (0.03-0.07), 0.10 (0.08-0.12), 0.15 (0.13-0.17), 0.20 (0.18-0.24), 0.30 or more (0.25-0.94). In the second model, we added the following list of potential confounding variables: age, sex, and the past three years' driving record.

Our second set of analyses focused solely on cannabis. To achieve this goal, we looked exclusively at drivers who had a confirmed BAC of zero. We present demographic characteristics and the 10 most frequent DRFs for these drivers, and used independent *t*-tests and Pearson's Chi-square tests to compare drivers who tested positive for cannabis and those who did not. We then present regression models (crude and adjusted) to determine the contribution of cannabis to DRFs. We report 95% and 99% confidence intervals (CI).

RESULTS

Alcohol data

Briefly, approximately two thirds of the sample were male, the mean age was 32.5 (SD = 8.6), and one of every two drivers in the sample had a driving record (see Table I). Table II and Figure 1 present the OR and CI of any DRF by BAC category. In Model 1, we present the crude association between DRFs and BAC. In Model 2, we

present the OR adjusted for potential confounders (age, sex, prior driving record). We found a clear relationship between increasing BAC and the OR of any DRF. These results replicate the known dose-response relationship between BAC and crash risk.

Cannabis data

Of the 32,543 drivers tested, 1,647 (5%) tested positive for cannabis. Drivers who tested positive were generally younger, male, and had a poorer driving record in the past three years (see Table III; all drivers had a confirmed BAC of zero). The 10 most frequently reported DRFs are presented in Table IV. A greater proportion of drivers who tested positive for cannabis had a DRF related to speeding or erratic/reckless driving.

The crude OR between DRFs and cannabis was 1.39 (99% CI = 1.21-1.59). After adjusting this association for age, sex, and driving record (see Table V) the OR for THC was 1.29 (99% CI = 1.11-1.50). Younger age and poorer driving records, but not sex, were also associated with a higher risk of a reported DRF.

DISCUSSION

The findings point to cannabis as a potential risk factor in fatal crashes. Individuals

who tested positive for cannabis but negative for alcohol had 29% excess risk (99% CI = 11-50) of having driven in a fashion that may have contributed to the crash, compared to drivers who tested negative for cannabis. This association was found after controlling for age, sex, and prior driving record. However, our findings likely reflect an underestimation of the actual effect of cannabis on driving. Given the long half-life of THC, it is possible that many drivers tested positive for cannabis without being impaired at the time of the crash. Furthermore, it is difficult to make the distinction between the presence of the active component of cannabis (THC), and its metabolites, which have no effects on the brain.²⁴

We found that 5% of the drivers tested positive for cannabis, but this number is not based on a representative sample. The authors of a study based on a representative sample of adults living in Ontario reported that only 1.9% of adults drove under the influence of cannabis in the previous year.²⁵ However, this number was 19.7% in a survey of Ontario high school students who had a driver's licence.²⁶ In a study of impairment in reckless drivers, more than half of those tested but not impaired by alcohol were impaired by some drug (cannabis was the most frequent).²⁷ These numbers may be related to young people's perception of the risks associated with cannabis use. Contrary to what many of them would report regarding alcohol, several consider cannabis to have a negligible effect on driving, and some even believe that cannabis may enhance driving.^{15,28,29} which suggests that we need to deal with these perceptions and attitudes.³⁰

We also replicated findings regarding alcohol.²¹ While this is not new, it increases our confidence in our results regarding cannabis and also allows us to put these findings in perspective. The frequency of drinking and driving and the severe impact of alcohol on driving abilities are well beyond what has been shown with cannabis, even if we consider that we may be underestimating the association. We also found, once more, that young males, and especially those with a bad driving record, were at greater risk of driving in an unsafe fashion, and controlled for these variables. This was important given that

TABLE III

Descriptive Statistics for Drivers Tested for THC and a BAC of Zero

Demographics	Cannabis Absent (N=30,896)	Cannabis Present (N=1,647)	χ^2/t^*	p-value
Age, mean (SD)	32.94 (8.88)	30.2 (8.44)	12.23	<0.001
Male, No. (%)	19,791 (64)	1296 (79)	146.72	<0.001
Driving Record – Any in the past three years	No. (%)	No. (%)		
Crashes	5174 (17)	295 (18)	1.52	0.22
DWI	767 (2)	74 (4)	25.12	<0.001
Other conviction	5831 (19)	502 (30)	134.40	<0.001
Speeding	7801 (26)	535 (33)	43.76	<0.001
License suspension/revocation	4229 (14)	419 (26)	177.86	<0.001
Any of the above	14,690 (48)	1013 (62)	122.02	<0.001

* Chi square values are presented for all variables with the exception of Age where the t-statistic is presented.

TABLE IV

The Top 10 Reported DRF from 1993 to 2003

Driver-related Factor	Cannabis Absent (N=30,896) No. (%)	Cannabis Present (N=1,647) No. (%)	χ^2	p-value
Failure to keep in proper lane	9074 (29.4)	494 (30.0)	0.29	0.59
Driving too fast for conditions or in excess of posted maximum	6072 (19.7)	428 (26.0)	39.24	0.001
Failure to yield right of way, obey signs or other safety zone traffic laws	3613 (11.7)	189 (11.5)	0.07	0.79
Erratic, reckless, careless or negligent vehicle operation	1715 (5.6)	146 (8.9)	31.85	<0.001
Making improper turn	1718 (5.6)	89 (5.4)	0.07	0.79
Overcorrecting	1270 (4.1)	57 (3.5)	1.69	0.19
Driving on wrong side of road (intentional or unintentional)	736 (2.4)	28 (1.7)	3.17	0.08
Passing with insufficient distance, or visibility, or failing to yield to overtaking vehicle	400 (1.3)	25 (1.5)	0.61	0.44
Improper or erratic lane changing	381 (1.2)	21 (1.3)	0.02	0.88
Following improperly	291 (0.9)	19 (1.2)	0.74	0.39
Any	18,405 (59.6)	1106 (67.2)	37.44	<0.001

others have reported statistical associations between cannabis use and traffic violations,³¹ and in one study the excess risk posed by cannabis was eliminated once drinking and driving behaviour and sex were considered.¹³ Hence, we are confident that the higher risk found in drivers who tested positive for cannabis cannot be explained by aggressive driving patterns or alcohol consumption.

One unanswered question is whether we could identify dosages at which cannabis may start to pose a crash risk, as has been done with alcohol.³² This question points to a lack of knowledge regarding the dose-response relationship between cannabis and driving, knowledge which is important to better educate drivers and support policy-making. For example, new procedures for roadside screening of cannabis use (using saliva) are highly predictive of actual use.³³ However, the successful implementation of such roadside testing may require the determination of the minimum blood con-

centration at which one does become "impaired" to safely drive an automobile.

The issue of safe driving and cannabis use is not restricted to recreational users; cannabis is increasingly used for medicinal purposes,³⁴ and long-term use of cannabis may create residual cognitive impairment.³⁵ Moreover, many conditions for which cannabis may be useful (e.g., glaucoma, cancer) are seen in older people; hence the effect of cannabis may be exacerbated by age-related changes in pharmacokinetics and/or the presence of other medications. Further studies are required to better understand the impact of cannabis on drivers who are using it as a medication.

We see our findings as additional evidence suggesting that cannabis may adversely affect drivers. The results are consistent with our knowledge of cannabis' effect on human performance and all mechanisms known to support safe driving.²⁴ Furthermore, the sample size allowed us to obtain narrow confidence

TABLE V

Odds Ratios with 95% and 99% CI for Models Predicting DRF

Main Variables	Odds Ratio (95% CI; 99% CI)
THC – Adjusted Model	1.29 (1.15, 1.45; 1.11, 1.50)
Confounding Variables	
Age	0.98 (0.98, 0.98; 0.98, 0.98)
Male	1.01 (0.96, 1.06; 0.94, 1.07)
Previous Accident	
None (reference)	
One in past three years	1.11 (1.04, 1.19; 1.02, 1.22)
Two or more in past three years	1.32 (1.16, 1.51; 1.11, 1.57)
Previous DWI	
None (reference)	
One in past three years	1.02 (0.86, 1.22; 0.81, 1.29)
Two or more in past three years	1.03 (0.67, 1.58; 0.59, 1.81)
Previous Other Moving Violation	
None (reference)	
One in past three years	1.12 (1.04, 1.21; 1.02, 1.23)
Two or more in past three years	1.25 (1.12, 1.40; 1.08, 1.45)
Previous Speeding Conviction	
None (reference)	
One in past three years	1.11 (1.04, 1.18; 1.02, 1.20)
Two or more in past three years	1.11 (1.01, 1.21; 0.99, 1.25)
Previous Licence Suspension/Revocation	
None (reference)	
One in past three years	1.36 (1.23, 1.50; 1.20, 1.54)
Two or more in past three years	1.67 (1.49, 1.87; 1.44, 1.93)

Appendix

Driver-related Factors

20	Leaving Vehicle Unattended in Roadway
21	Overloading or Improper Loading of Vehicle with Passengers or Cargo
22	Towing or Pushing Vehicle Improperly
23	Failing to [Dim Lights or, Since 1995] Have Lights on When Required
24	Operating without Required Equipment
25	Creating Unlawful Noise or Using Equipment Prohibited by Law
26	Following Improperly
27	Improper or Erratic Lane Changing
28	Failure to Keep in Proper Lane or Running off Road
29	Illegal Driving on Road Shoulder, in Ditch, on Sidewalk, on Median
30	Making Improper Entry to or Exit from Trafficway
33	Passing where Prohibited by Posted Signs, Pavement Markings, Hill or Curve, or School Bus
	Displaying Warning not to Pass
34	Passing on Wrong Side
35	Passing with Insufficient Distance or Inadequate Visibility or Failing to Yield to Overtaking Vehicle
36	Operating the Vehicle in Other Erratic, Reckless, Careless or Negligent Manner [or Operating at Erratic or Suddenly Changing Speeds, Since 1995]
37	Traveling on Prohibited Trafficway (Since 1995)
38	Failure to Yield Right of Way
39	Failure to Obey Traffic Signs, Traffic Control Devices or Traffic Officers, Failure to Observe Safety Zone Traffic Laws
40	Passing Through or Around Barrier Positioned to Prohibit or Channel Traffic
41	Failure to Observe Warnings or Instructions on Vehicles Displaying Them
42	Failure to Signal Intentions
43	Giving Wrong Signal
44	Driving Too Fast for Conditions or in Excess of Posted Speed Limit
45	Driving Less than Posted Maximum
46	Operating at Erratic or Suddenly Changing Speeds
47	Making Right Turn from Left Turn Lane or Making Left Turn from Right Turn Lane
48	Making Improper Turn
49	Driving Wrong Way on One-Way Trafficway
50	Driving on Wrong Side of Road [(Intentionally or Unintentionally) Since 1995]
51	Operator Inexperience
52	Unfamiliar with Roadway
53	Stopping in Roadway (Vehicle not Abandoned)
54	Underriding a Parked Truck
55	Getting Off/Out of or On/Into Moving Transport Vehicle
56	Getting Off/Out of or On/Into Non-Moving Transport Vehicle
57	Improper Tire Pressure (Since 1995)
58	Locked Wheel (Since 1995)
59	Overcorrecting (Since 1995)

intervals around our point estimates and allowed for the control of important confounders; others have reported similar risk estimates but could not rule out the play of chance because of small sample sizes.^{36,37} Yet, these estimates appear small compared

to alcohol and some prescription medications (e.g., long-acting benzodiazepines). Nonetheless, we remain cautious because we lacked knowledge about drug concentrations and we could not fully ascertain responsibility for crashes. Possibly the best

approach to resolve the issue will be to determine the dose-response relationship between THC and driving performance.

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RÉSUMÉ

Contexte : On sait que le cannabis a des effets nuisibles sur les performances humaines et qu'il pourrait aussi nuire à la conduite d'un véhicule. Cependant, les études sur le sujet donnent des résultats peu probants. Dans notre étude, nous avons cherché à approfondir la question des effets du cannabis sur la conduite.

Méthode : Nous avons mené une étude cas-témoin transversale auprès de conducteurs de 20 à 49 ans impliqués dans des accidents mortels aux États-Unis entre 1993 et 2003; nous n'avons inclus que les conducteurs ayant fait l'objet d'un test de dépistage du cannabis, mais dont le taux d'alcoolémie était nul. Les cas étaient des conducteurs ayant commis au moins un acte de conduite potentiellement dangereux dans le contexte de l'accident (p. ex., dépasser la limite de vitesse); les témoins étaient des conducteurs dont la conduite n'avait pas été dangereuse lors de l'accident. Nous avons calculé les rapports de cotes (RC) bruts et ajustés de tout acte de conduite potentiellement dangereux chez les conducteurs déclarés positifs pour le cannabis, mais négatifs pour la consommation d'alcool. Dans notre calcul des RC ajustés, nous avons tenu compte de l'âge, du sexe et du dossier de conduite antérieur.

Résultats : Cinq p. cent des conducteurs avaient été déclarés positifs pour le cannabis. Le RC brut d'un acte de conduite potentiellement dangereux était de 1,39 (IC de 99 % = 1,21-1,59) pour les conducteurs déclarés positifs. Même compte tenu de l'âge, du sexe et du dossier de conduite antérieur, la présence de cannabis demeurait associée à un risque plus élevé d'avoir eu une conduite potentiellement dangereuse (1,29, IC de 99 % = 1,11-1,50).

Conclusion : Le cannabis a eu un effet néfaste sur la conduite, comme on pouvait le prédire d'après les études de performance humaine. Cette constatation confirme la nécessité d'intervenir pour réduire la prévalence de la conduite avec facultés affaiblies par le cannabis et montre qu'il faudrait pousser la recherche sur la relation dose-réponse entre le cannabis et la prudence au volant.

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