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Highlights

- We examined combined THC/Alcohol crash culpability in fatal car crashes.
- Since 1991, a five-fold increase in combined THC/Alcohol prevalence has occurred.
- Each .01 BAC unit increased the culpability odds (COs) by approximately 9-11%.
- Drivers who were positive for THC alone had 16% increased COs.
- Combined THC/Alcohol COs were greater than COs for alcohol or THC alone.

The Combined Effects of Alcohol and Cannabis on Driving: Impact on Crash Risk

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Background/objectives: Driving under the influence of alcohol or cannabis alone is associated with increased crash risk. This study explores the combined influence of low levels of alcohol (BAC ≤ .08) and cannabis on crash risk.

Materials and Methods: Drivers aged 20 years or older who had been tested for both drugs and alcohol after involvement in a fatal crash in the United States (1991-2008) were examined using a case-control design. Cases were drivers with at least one potentially unsafe driving action (UDA) recorded in relation to the crash (e.g., weaving); controls had none recorded. We examined the prevalence of driving under the influence of alcohol, cannabis, and both agents, for drivers involved in a fatal crash. Adjusted odds ratios of committing an UDA for alcohol alone, THC alone, and their combined effect were computed via logistic regression and adjusted for a number of potential confounders.

Results: Over the past two decades, the prevalence of THC and alcohol in car drivers involved in a fatal crash has increased approximately five-fold from below 2% in 1991 to above 10% in 2008. Each .01 BAC unit increased the odds of an UDA by approximately 9-11%. Drivers who were positive for THC alone had 16% increased odds of an UDA. When alcohol and THC were combined the odds of an UDA increased by approximately 8-10% for each .01 BAC unit increase over alcohol or THC alone.

Conclusion: Drivers positive for both agents had greater odds of making an error than drivers positive for either alcohol or cannabis only. Further research is needed to better examine the interaction between cannabis concentration levels, alcohol, and driving. This research would support enforcement agencies and public health educators by highlighting the combined effect of cannabis at low BAC levels.

Key Words: Crash Culpability; Impairment; THC; Alcohol; Car Drivers

Introduction

Driving while under the influence of alcohol or illicit drugs continues to be a concern in developed countries. This behaviour contributes to many motor vehicle crashes. As one example, drink-driving was a factor in almost 30% of Canadian motor vehicle fatalities that occurred in 2003 through 2005 [1]. In the United States, the 2009 National Survey on Drug Use and Health estimated that 30.2 million persons aged 12 years or older had driven under the influence of alcohol at least once during the past year, and 10.5 million persons had driven under the influence of illicit drugs, with young adults aged 21 to 29 years more likely to report these behaviours [2].

Alcohol is the drug detected most frequently in drivers fatally injured in a crash or hospitalized following a crash, while cannabis is one of the most frequently detected illicit drugs [3-6]. Many drivers are found to be under the influence of both alcohol and cannabis[5-13]. For example, Biechler [8] found that 40% of drivers involved in a fatal crash in France who tested positive for cannabis also had a blood alcohol concentration (BAC) level above the legal limit of 0.05 g/dL, raising questions about their combined effect on drivers.

Alcohol has been consistently shown to have a dose-related effect on driving performance [13,14]. However, the effect of cannabis on driving performance is less well established. Research generally shows that recent cannabis use impairs some measures of simulated and on-road driving performance [15-20] and increases the risk of crash involvement [11,21-24] in a dose-related manner [15,25] but others found no statistically significant effect [25-32]. One potential reason for this discrepancy may be that drivers impaired by cannabis are often aware of their impairment and employ behavioural strategies to compensate, such as driving more slowly and increasing their following distance [14-16,20]. It is also possible that THC detection methods may be responsible for this discrepancy. As compared to measuring THC concentration in blood samples, alternative methods such as urine or hair analysis can detect the presence of cannabis metabolites long after ingestion, and presumably long after any impairing effects have dissipated [29]. THC concentration in the blood, on the other hand, is a much more acute measure. In a study conducted by Drummer, Chu and

Gerostamoulos[33], the authors noted that among 3,400 Australian accidents analyzed using blood sampling to test for cannabis consumption, the odds ratio of being responsible for an accident was 3.0(95% CI: 1.19,7.62)[1] compared to those cases drug-negative. Further, when cases were positive for carboxy-THC a metabolite commonly detected via urine testing the odds of culpability did not differ compared to the drug-negative referent (OR: 0.8; 95%CI: 0.51, 1.28) However THC-only blood positive cases had increased odds of culpability compared to those cases positive for carboxy-THC only (OR: 3.75; 95% CI: 1.34; 10.45). Nonetheless, reviews generally find that only higher doses of cannabis are associated with elevated crash risk and impaired driving skills [25,29]. In a recent meta-analysis of nine culpability or case-control observational studies, acute cannabis consumption was estimated to increase the odds of collision resulting in serious injury or death by 92% (pooled OR: 1.92; 95% CI: 1.35, 2.73) [34].

Although law enforcement efforts in recent years have attempted to decrease driving under the influence of drugs, research suggests that the number of people driving under the influence of cannabis is increasing [5,35-39]. For example, a 10-year study of apprehended drivers in Sweden showed 18% tested positive for delta-9-tetrahydrocannabinol (THC; the main psychoactive chemical compound in cannabis) in 1995, while 29% tested positive in 2004[37].

The effect on driving of alcohol and cannabis combined appears to be greater than that of either drug alone, with research generally suggesting that the effect is additive [10,14,25,32,40-42] or possibly synergistic [8,9,25,32,43,44], although some research has found no additive effect [11,45,46]. Of particular interest is the combined effect at low doses (i.e., when their BAC is below the legal limit). Research in this area shows inconsistent results. Lamers [45] found that a low dose of alcohol (i.e., producing a BAC of 0.04-0.05 g/dL) combined with a small dose of THC (100 µg/kg) produced no statistically significant difference in the on-road driving proficiency test compared with alcohol-and-drug-free drivers. However, driver

[1] Data were obtained from Drummer, Chu, and Gerostamoulos 2001, Table 1. Odds ratios and 95% confidence intervals were calculated using VassarStats website, located at: http://vassarstats.net/odds2x2.html.

visual search frequency at intersections was reduced by 3% (p=.041) and this effect was most pronounced in female drivers (7% decline in females, 0.3% decline in males). Conversely, Robbe [47] and Robbe and O'Hanlon [48] found that on-road driving performance was severely impaired when low doses of alcohol (BAC of 0.04 g/dL) and THC (100 or 200 µg/kg) were combined, while administering each of these doses alone produced only minor impairment (for the alcohol dose and THC dose of 100 µg/kg) or moderate impairment (for the THC dose of 200 µg/kg).

The present study was conducted to expand on those findings by examining the combined effect of alcohol and THC using fatal motor vehicle crash data. First, we examined the prevalence of driving under low BAC levels, cannabis, and both substances. We hypothesized that alcohol-detection would show a decreasing trend from 1993 through 2008, while cannabis-detection and cannabis combined with alcohol would show increasing trends. Second, we examined the combined effects of low BAC and THC on driving. We hypothesized that the combined effects of alcohol and THC would increase the odds of a driver committing an unsafe driver action compared with alcohol and THC free drivers.

Materials and Methods

Data Source

Driver crash data were drawn from the Fatality Analysis Reporting System (FARS) compiled by the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration, U.S.A. From this dataset we derived our proxy measure of responsibility (i.e., presence of one or more unsafe driver actions), cannabis and alcohol exposure, and also driver age, sex, medication usage, and driver history. Full details regarding the data source used are published elsewhere [49].

Inclusion Criteria

For inclusion in this study, drivers were required to have a valid blood alcohol content (FARS recorded range: 0 thru .94 BAC grams per deciliter) obtained by blood test. Further, all drivers had at least one confirmed blood

drug test. We limited our analyses to drivers of passenger vehicles, sport-utility vehicles and light trucks (pick-up trucks) only. Drivers aged less than 20 were excluded as they would not have had sufficient time to acquire a driving history.

Proxy measure of responsibility

The FARS data source includes several driver-related crash factors. Factors 20-60 are unsafe driver actions (UDAs) that may have contributed to crash initiation [50]. For this study, drivers with at least one UDA recorded were considered to have contributed to the crash; those drivers with no UDAs were considered not to have contributed to crash initiation. As a proxy measure of responsibility, UDAs are preferred over traffic violations as a method of estimating the contribution of each driver involved in a crash given traffic violations can be underreported due to the requirement of legal proof or given they may not be chargeable offences [50]. Further, the validity of UDAs has been examined using crash-configurations where crash responsibility can be inferred (e.g., head on, rear-end). The driver of the striking vehicle is typically assigned the majority of UDAs [50] and we have also demonstrated this association [51].

Cannabis, and other drug classification and exposure

Detailed results from drug tests are available from FARS from 1991 onward. This study examines data from 1991 to 2008. Between the years 1991 and 1992, drugs were recorded by group (e.g., Cannabis; Depressants). From 1993 to present (2008) drugs are classified individually (e.g., Hashish; Diazepam) within each drug group. The following THC containing drugs are recorded in FARS: Delta 9 (600); Hashish Oil (601); Hashish (602); Marijuana (603); Marinol (604); Tetrahydrocannabinoid (605); THC (606); Cannabinoid, Type Unknown (695). For each driver, either one (1991 and 1992) or up to three serum analyses were available (1993-2008). Given this change in drug collection, for the primary analysis we only considered drivers who tested positive for one THC drug alone. The FARS database also captures various other drug classes that are known to impact driving including: Depressants,

Narcotics, Stimulants, and Other Drugs (Hallucinogens, PCP, Anabolic Steroids, and Inhalants). We considered drivers to be positive for these other drugs if they had a positive serum analysis result.

Previous Driving History

To control for high risk driving habits, we also included variables containing the drivers' past three-year driving records. Previous driving history included: crashes, recorded convictions for driving while impaired (DWI; includes both alcohol and drugs), speeding convictions (going too fast or too slow), other harmful moving violation convictions, and license suspensions and revocations.

Statistical Analyses

Descriptive statistics (means and proportions) were used to present drivers' age, sex, previous driving history, and drug status by alcohol/THC exposure (Alcohol and THC free, Alcohol Only, THC Only, THC plus Alcohol). The Pearson Chi-Square test was used to formally compare driver characteristics by alcohol/THC exposure with the exception of age which was compared across groups using a One-way Analysis of Variance (ANOVA).

Prevalence of THC detection is presented graphically for THC alone, THC plus alcohol, and any THC (either THC or THC plus Alcohol) by year from 1991 to 2008. Both unadjusted and adjusted prevalence are presented. Unadjusted prevalence was calculated as the number of exposed drivers divided by all drivers with a valid drug and alcohol blood test. We also present adjusted prevalence estimates that assume the proportion of drivers tested remains constant at the proportion observed in the first year of individual drug classification (1993) to account for the potential impact of increased drug screening over time on the observed prevalence.

Logistic regression was used to examine the effects of alcohol, THC, and their combination. Initially, we examined the presence of UDAs by alcohol and THC exposure without adjustment for other factors (Model 1).

Given that we expected the effect of alcohol to plateau at higher levels we included both the linear and quadratic alcohol terms. Next, we examined the potential interaction between alcohol and THC (Model 2); third, we explored the impact of alcohol and THC adjusted for driver age and sex and their interaction (Model 3) using a step-down hierarchical procedure[52]. The quadratic age term was also included given the possibility of a curvilinear relationship between a driver's age and committing an UDA. The final model (Model 4) included driver's age (both linear and quadratic terms), sex, BAC (both linear and quadratic terms), and the interaction between both sex and BAC with age. Given the potential for poly-drug presence, we also adjusted for other drugs and medications and to control for inherent risk taking behaviour we included the driver's previous driving history. The final model was used to calculate predicted odds and odds ratios (with 95% confidence intervals) for alcohol, THC, and their combination [53].

Results

Between the years 1991 and 2008 there were 834,328 drivers of cars involved in a fatal crash. Of these, 722,267 met our inclusion criteria for age (20 or greater). We excluded 47 drivers for whom sex was not coded, leaving 722,220 drivers. Of these, 150,010 drivers were blood tested for both alcohol and drugs and comprise the sample used for analysis. The remaining drivers were either not blood tested for alcohol (397,396) or blood tested for alcohol but not blood tested for drugs (174,814) and these drivers were excluded from the analysis. A comparison of these three groups on driver characteristics is provided in Appendix 1. Of the 150,010 drivers blood tested for alcohol and drugs, 87,280 were alcohol and THC free, 53,992 tested positive for alcohol only, 3,387 tested positive for THC only, and 4,347 tested positive for both THC and alcohol. Further an additional 1,004 drivers had either two (N=909) or three (N=95) THC positive tests – however, these drivers were not included in the primary analyses. Drivers testing positive for alcohol, THC, or both tended to be younger, male, have a poorer driving record compared to those drivers testing negative for both substances. Polydrug use was most prevalent

in drivers testing positive for THC and stimulants were the most frequently detected medication class. See Table 1 for the full results.

Compared to 1991, the unadjusted prevalence of THC detection increased from less than two percent in 1992 to almost 8% in 2008 (see Figure 1: Panel A). For all years, greater percentages of THC were detected in combination with alcohol versus THC alone. On average, the percentage difference between THC detected alone and in combination with alcohol was approximately 29% and ranged between 7% (1997) and 44% (1995). In 1991, approximately 30% of those tested for alcohol were tested for drugs, by 2008 this has increased to 70%. Therefore, we also present an adjusted prevalence estimate (see Figure 1: Panel B). After adjustment for increased testing, THC detection appears to be relatively stable during the study time period with moderate increases in THC positive drivers in more recent years.

Both alcohol and THC increased the odds of committing an UDA. When BAC increases from .00 to .01 the odds of an UDA increases by 11% (Model 1 – Adjusted OR: 1.11; 95%CI: 1.110; 1.118). For subsequent BAC increases (e.g., from .01 to .02), the statistically significant BAC quadratic term indicated that each .01 BAC increment was slightly lower than the previous unit's increase (Model 1 – Adjusted OR: 0.99; 95%CI: 0.99; 0.99 – see the appendix for a worked example, specifically [1] thru [6]). Testing positive for THC increased the odds of performing an UDA by 28% (Model 1 – Adjusted OR: 1.28; 95%CI: 1.21; 1.36) when the model only included THC and the linear and quadratic BAC terms. The linear BAC by THC interaction was statistically significant (Wald Statistic = 18.16, p <.001; Model 2). Age and Sex interacted significantly with both alcohol and each other but not THC (Model 3). Therefore, the final model included age (both linear and quadratic terms), sex, alcohol (both linear and quadratic terms), THC, other medications, previous driving history, Age by Sex, Age-squared by Sex, Age by Alcohol exposure, Age-squared by Alcohol exposure, and Alcohol by THC exposure (Model 4).

The full results of Model 4 are displayed in Table 2. The significant age-squared term implied that age has a curvilinear fit (versus linear). In fact, the age-term had the greatest impact on increasing the odds of an UDA for the

youngest and oldest drivers. The interaction between Age and BAC was similar to an inverted "J" in shape. For example, comparing male THC negative drivers with a BAC=.08 to male THC negative drivers with a BAC=.00 for driver ages 20, 40, 60 and 80 the odds ratios were 1.98, 2.18, 1.99, and 1.49 respectively. In other words, the odds of committing an UDA preceding a fatal crash were increased from age 20 until around the age of 40 at which point odds began to decrease. Finally, driver sex did interact significantly with driver age (Wald(1) = 5.39, p = .021). Essentially, males had greater predicted odds of committing an UDA compared to females and given the curvilinear relationship between age and UDAs, this difference was most pronounced in the youngest and oldest drivers.

Even after controlling for age, sex, alcohol, THC use, and previous driving history, depressants, narcotics, stimulants, and other medications increased the odds of an UDA by 55%, 33%, 84%, and 15% respectively. Further, poorer driving record resulted *in increased odds of an UDA*. The most pronounced effect was seen with both prior crash or suspensions where the odds of an UDA were increased between 13% (one prior crash) and 39% (three or more prior crashes) and 26% (one prior suspension) and 33%(three or more prior suspensions).

After adjusting for driver age and sex, alcohol, other medications, and previous driving history, drivers testing positive for THC with a BAC = .00 had an OR of 1.165 (95% CI: 1.082;1.255) relative to those not positive for THC. The linear BAC odds ratio was 1.115 (95% CI: 1.110; 1.120) and the quadratic BAC odds ratio was 0.998 (95% CI: 0.998; 0.999) per one unit BAC increment (i.e., .01). The THC by BAC interaction odds ratio was 0.987 (95% CI: 0.981; 0.994) indicating that the effect of combining these two substances was greatest at lower levels of BAC. Please see the appendix for a detailed review of predicted odds, odds ratios, and interaction effects that can be obtained from the final model.

Figure 2 demonstrates the impact on committing an unsafe driver action for several terms included in the model. The Age and Age^2 terms indicate that the youngest and oldest drivers had the highest log odds of an UDA, and the middle-aged drivers had the lowest. We see this pattern clearly

in the Female Drivers panel of Figure 2, specifically examining the THC lines when BAC = 0 for drivers aged 25, 45, and 65. For Male drivers, this pattern was not as prominent given drivers aged 65 had noticeably lower odds than drivers aged 25 (but still higher odds compared to drivers aged 45). The different y-values by sex when BAC = 0 are a result of the statistically significant Age *by* Sex term. The impact of the Age by BAC and Age^2 by BAC interaction terms is visible in the slope of each of the lines. Regardless of driver sex, middle-aged drivers, closely followed by younger drivers, had the steepest slopes – in other words increasing BAC levels had the greatest impact on driver culpability in these age groups. The slopes for the lines representing drivers aged 65 are somewhat flatter indicating driver culpability was less impacted by increasing BAC levels in older drivers. Finally, note how the THC and No THC lines by driver age get closer as BAC increases, representative of the negative THC by BAC interaction term.

As noted earlier, 1,004 drivers had two or more THC positive tests and these drivers were excluded from the primary analysis. To examine the impact of multiple positive THC tests on crash responsibility, we ran the final model for the time period 1993-2008, including all drivers testing positive for THC. The THC variable was coded as 0, 1, or 2 or more positive THC detections and we examined both the linear and quadratic contrasts. When BAC = 0, the log-odds of committing an unsafe driver action were 1.61, 1.78, and 1.93 for drivers with 0, 1, or 2 or more positive detections. The linear trend was statistically significant (Linear Polynomial Contrast Estimate = .225, SE=.072, Wald Chi-Square(1)=9.8, p=.002), the quadratic trend was not (Quadratic Polynomial Contrast Estimate = -.002, SE=.051, Wald Chi-Square(1)=.001, p=.972). Compared to THC negative drivers, the odds ratio of committing an unsafe driver action were 1.18 (95% CI: 1.09; 1.27) for one detection and 1.38 (95% CI: 1.13; 1.68) for two or more positive THC detections.

Discussion

Over the past two decades, the prevalence of alcohol and THC in car drivers has increased approximately five-fold from below 2% in 1991 to above

10% in 2008. Other studies report THC prevalence estimates similar to those found in our sample. Studies examining drivers involved in motor vehicle crashes using both blood tests [3,12,54,55] and combination blood/urine tests [56] have reported prevalence estimates ranging between 4% and 12%. It should be noted that the increase seen in our study may simply be an artefact of increased testing rates for drivers also tested for alcohol. Annual test rates increased from 30% in 1991 to approximately 70% in 2008. After adjustment for the 1993 annual test rate (the initial year of individual drug classification) prevalence estimates appear much more stable ranging between 1.5% in 1991 to as high as 4.6%. Despite adjustment however, from 1996 on prevalence was consistently above 3%, and from 2002 on above 3.5% indicating a trend of increasing prevalence of THC presence in fatal crashes. After adjusting for driver age, sex, alcohol, polydrug use, and previous driving record, car drivers with a confirmed BAC=0.00 testing positive for THC had 16% increased odds of committing an unsafe driver action, a proxy measure of crash responsibility, compared to drivers testing negative for THC. This is somewhat lower than the 29% reported by Bédard and colleagues [24]. However, results reported in the current article are derived from a more sophisticated model that included a wider demographic (e.g., drivers aged 50+) and accounted for the fact that the driver may be under the influence of alcohol and other drugs.

Drivers at typical BAC legal limits of .05 and .08 had greater odds of committing an UDA of 66% and 117% respectively compared with sober, THC-free, drivers. When combined with THC these odds increased to 81% and 128% respectively. As noted, the THC and alcohol combination effect was most pronounced at the lowest levels of BAC. In other words, as BAC level increases the impairing effects of alcohol dominate the relationship between THC and alcohol. Given these results, public health education should consider highlighting the association between low levels of alcohol, cannabis, and crash risk.

A relatively large number of THC positive drivers were under the influence of more than one substance. For example, out of the total 7,734 drivers positive for THC approximately 56% (N=4,347) were also positive for

BAC and 31% (N=2,433) tested positive for another drug substance. Aside from alcohol the most likely other drug substance that THC positive drivers tested positive for were stimulants (18%; N=1,386). It should be noted that stimulants, depressants, narcotics, and other medications (Hallucinogens, PCP, Anabolic Steroids, and Inhalants) increased the odds of an UDA by 84%, 55%, 33%, and 15% respectively.

Our approach does have certain limitations. For example, the FARS database does not capture route of administration, blood concentration level at the time of crash, or dosage level – we simply have a dichotomous marker of THC presence. However, THC can remain in the blood for hours or even days [57] which increases the possibility that some drivers testing positive for THC were not impaired resulting in our study results underestimating the true culpability odds[24]. Another limitation of the FARS database is that we do not know why THC was present in drivers. For many drivers THC presence is likely indicative of recreational use, however the prevalence of therapeutic use is increasing, especially as individual states legislate legal use of THC for medical purposes [58]. Given this, there is the potential for underlying conditions (e.g., sleep disorders, musculoskeletal disorders) to partially account for the increased odds associated with THC presence.

Many strengths of this our study are derived from the analytical approach taken. For example, the number of fatal crashes examined allowed us to control for driver age, sex, driver record, and poly-drug use. Further, the large sample size that FARS provides allowed for increased precision which translated into relatively narrow confidence intervals around the odds ratios [34]. Also, we used the final analysis model to fully explore the combination of alcohol and THC by driver age, sex, and number of THC detections.

Conclusion

Drivers positive for both alcohol or cannabis had greater odds of making an error than drivers positive for either alcohol or cannabis only. Further research to better examine the interaction between low to legal (e.g., .05 and .08 BAC grams per deciliter) levels *of* alcohol, cannabis concentration levels (versus simply a dichotomous measure), and specific driving

behaviours is necessary. This research would support enforcement agencies in establishing appropriate road-side screening interventions to determine impairment and public health educators to highlight the additive effect of cannabis at low BAC levels, levels that may not have been traditionally considered impairing.

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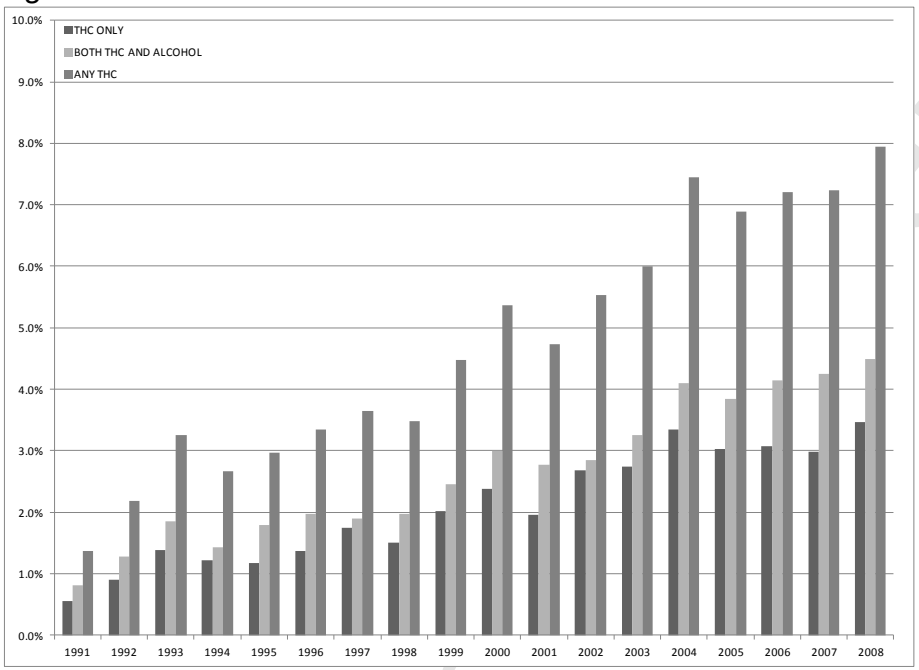
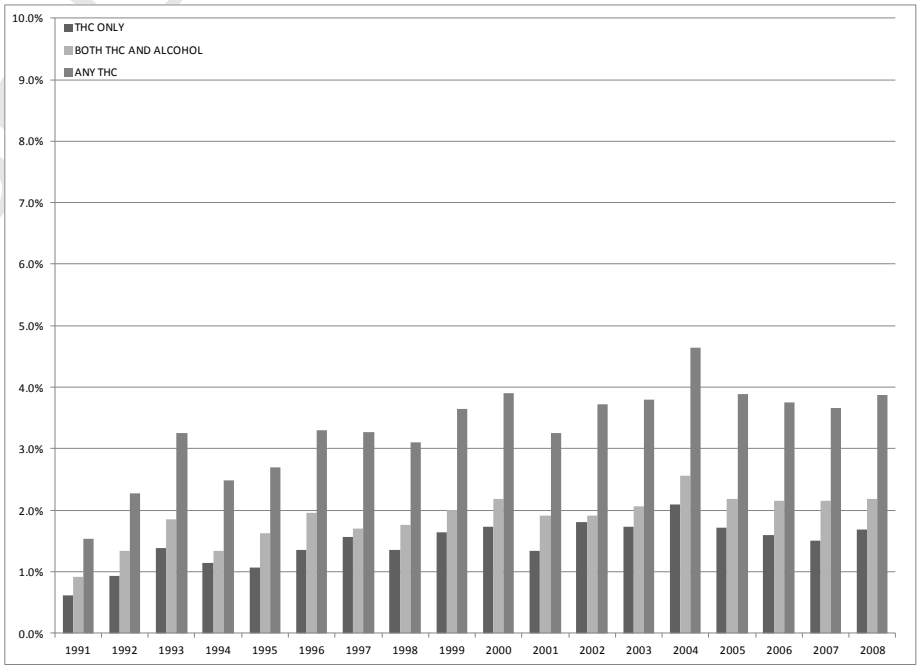
Figure 1. The Prevalence of THC and THC + Alcohol Detections over Time



Panel A: Unadjusted



Panel B: Adjusted for 1993 test-rate

Figure 2: Log odds of an unsafe driver action by age, sex, BAC level, and THC status

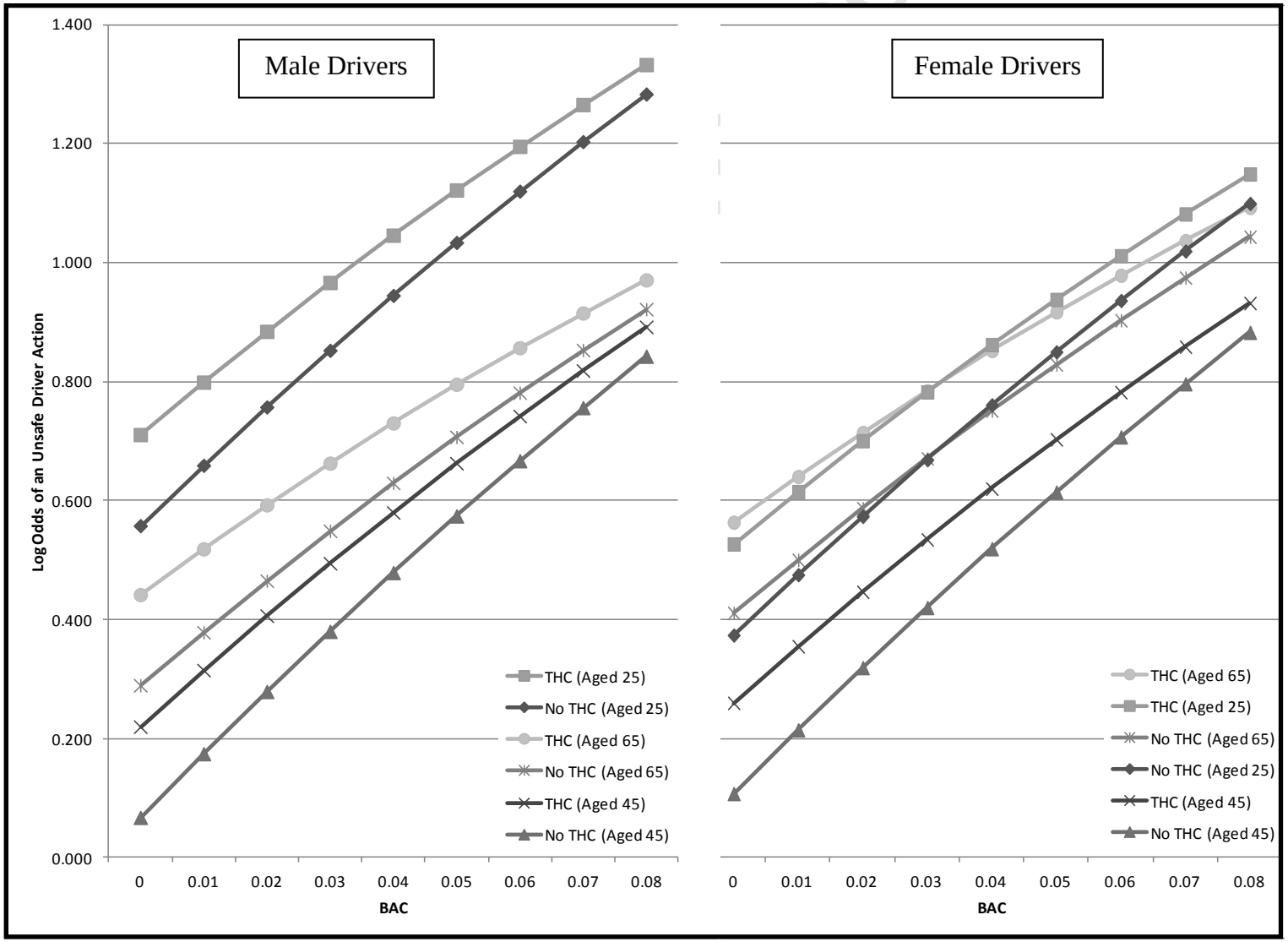


Table 1: *Demographic Information by Group**

Characteristic	Alcohol and THC Free (N=87,280)	Alcohol Only (N=53,992)	THC Only (N=3,387)	Alcohol + THC (N=4,347)	F/χ^2 **	*p* Value
Age, Mean (SD)	46.49 (19.2)	35.68 (13.1)	32.51 (11.4)	30.71 (9.6)	5,599	<.001
Male, No (%)	56,083 (64.3)	44,547 (82.5)	2,670 (78.8%)	3,703 (85.2)	5,979	<.001
Previous Driver History, No. (%)***						
Crashes, No (%)	12,679 (15.8)	8,600 (17.2)	561 (18.0)	745 (18.3)	61	<.001
DWI, No (%)	1,519 (1.8)	5,607 (10.6)	149 (4.5)	505 (11.8)	5,454	<.001
Other Convictions, No (%)	13,383 (15.5)	12,266 (23.2)	989 (29.6)	1,223 (28.5)	1,760	<.001
Speeding, No (%)	16,197 (18.8)	12,698 (24.0)	1,037 (31.0)	1,217 (28.4)	862	<.001
License Suspension, No (%)	8,440 (9.8)	13,761 (26.0)	895 (26.8)	1,415 (33.0)	7,285	<.001
Any of Above, No (%)	33,860 (41.2)	29,037 (56.5)	2,005 (62.1)	2,686 (64.2)	3,690	<.001
Other Medications, No (%)						
Depressant, No (%)	3,622 (4.1)	2,297 (4.3)	318 (9.4)	290 (6.7)	270	<.001
Narcotic, No (%)	3,396 (3.9)	1,282 (2.4)	225 (6.6)	123 (2.8)	352	<.001
Stimulant, No (%)	4,349 (5.0)	4,831 (8.9)	711 (21.0)	675 (15.5)	2,334	<.001
Other, No (%)	5,253 (6.0)	3,118 (5.8)	217 (6.4)	222 (5.1)	10.2	.017
Any of the Above, No (%)	13,479 (15.4)	9,794 (18.1)	1,253 (37.0)	1,180 (27.1)	1,453	<.001

* Please note that while drivers may be alcohol or THC free, other drugs may be present
** F-statistic given for age; Chi Square value given for all other descriptors.
*** For Previous Driver History, percentage based on valid percent. Missing data as follows: Crashes, 7.8%; DWIs, Other Convictions, Speeding, License Suspension, 1.6%; Any of the Above, 5.4%.

Table 2: *Coefficients and Odds Ratios with 95% CI for the final model predicting Unsafe Driver Actions*

Variable, referent		B (S.E.)	Odds Ratio (95% CI)
Age (decades, centered at 45 years)		0.009 (0.007)	1.009 (0.995;1.024)
Age^2		0.071 (0.004)	1.074 (1.067;1.081)
BAC, 0.00 g/100 ml		0.109 (0.002)	1.115 (1.110;1.120)
BAC^2		-0.002 (0.000)	0.998 (0.998;0.999)
Sex, female		-0.074 (0.019)	0.929 (0.894;0.965)
Age × BAC		-0.003 (0.001)	0.997 (0.996;0.998)
Age^2 × BAC		-0.003 (0.000)	0.997 (0.996;0.998)
Age × Sex		-0.076 (0.008)	0.926 (0.911;0.942)
Age^2 × Sex		0.018 (0.004)	1.018 (1.010;1.026)
Depressants, none		0.440 (0.034)	1.553 (1.451;1.662)
Narcotics, none		0.288 (0.037)	1.334 (1.241;1.435)
Stimulants, none		0.608 (0.029)	1.837 (1.734;1.945)
Other Medications, none		0.139 (0.029)	1.149 (1.085;1.216)
THC Exposure, none		0.153 (0.038)	1.165 (1.082;1.255)
THC Exposure × BAC		-0.013 (0.003)	0.987 (0.981;0.994)
Crashes,	One	0.120 (0.019)	1.128 (1.086;1.172)
	Two	0.238 (0.043)	1.268 (1.165;1.381)
	Three or more	0.326 (0.084)	1.385 (1.174;1.634)
DWI,	One	-0.047 (0.041)	0.954 (0.881;1.033)
	Two	0.002 (0.097)	1.002 (0.829;1.211)
	Three or more	-0.063 (0.216)	0.939 (0.615;1.434)
Speeding,	One	0.054 (0.019)	1.055 (1.017;1.095)
	Two	0.102 (0.033)	1.107 (1.038;1.181)
	Three or more	0.123 (0.046)	1.131 (1.033;1.239)
Suspensions,	One	0.228 (0.027)	1.256 (1.192;1.324)
	Two	0.285 (0.041)	1.329 (1.227;1.440)
	Three or more	0.284 (0.040)	1.329 (1.229;1.436)
Other,	One	0.111 (0.020)	1.117 (1.074;1.163)
	Two	0.151 (0.038)	1.163 (1.080;1.253)
	Three or more	0.214 (0.051)	1.239 (1.121;1.369)
Constant		0.140 (0.017)	

Table 3. Predicted odds and adjusted odds ratios of any unsafe driver action by BAC and THC exposure.*

	Predicted Odds		Odds Ratio (95% CI) Alcohol Alone (B:A)	Odds Ratio (95% CI) Alcohol & THC Combined (C:A)
BAC	**THC -**	**THC +**		
0.00	1.07[A,B]	1.25[C]	1.00 (NA)	1.16 (1.08;1.26)
0.01	1.19[B]	1.37[C]	1.11 (1.11;1.12)	1.28 (1.19;1.38)
0.02	1.32[B]	1.50[C]	1.24 (1.23;1.25)	1.40 (1.31;1.50)
0.03	1.46[B]	1.64[C]	1.37 (1.35;1.38)	1.53 (1.44;1.64)
0.04	1.61[B]	1.79[C]	1.51 (1.49;1.53)	1.67 (1.57;1.78)
0.05	1.78[B]	1.94[C]	1.66 (1.63;1.69)	1.81 (1.70;1.93)
0.06	1.95[B]	2.10[C]	1.82 (1.78;1.86)	1.96 (1.84;2.09)
0.07	2.13[B]	2.27[C]	1.99 (1.94;2.04)	2.12 (1.99;2.26)
0.08	2.32[B]	2.44[C]	2.17 (2.11;2.23)	2.28 (2.13;2.44)

* Computed for Male drivers centered at 45 years of age. Note that computed predicted odds and odds ratios reported are rounded at two decimal places. Therefore the computed odds ratios reported may be slightly different than simply dividing the rounded predicted odds (B:A or C:A) displayed in the above table.