Scandinavian Journal of Public Health

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What is This?

ORIGINAL ARTICLE

Prevalence of alcohol and other drugs and the concentrations in blood of drivers killed in road traffic crashes in Sweden

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Abstract

Background: Drunk or drug-impaired drivers represent a major public health and societal problem worldwide. Because over 95% of drivers killed on the roads in Sweden are autopsied, reliable information is available about the use of alcohol and/or other drug before the crash. *Methods*: This retrospective 4-year study (2008–2011) used a forensic toxicology database (TOXBASE) to evaluate the concentrations of alcohol and other drugs in blood samples from drivers killed in road-traffic crashes. *Results*: The mean age of all victims ($N = 895$) was 48 ± 20 years, and the majority were male (86%). In 504 drivers (56%), the results of toxicological analysis were negative and these victims were older; mean age (± SD) 47 ± 20 years, than alcohol positive cases (35 ± 14 years) and illicit drug users (34 ± 15 years). In 21% of fatalities, blood-alcohol concentration (BAC) was above the statutory limit for driving (0.2 g/L), although the median BAC was appreciably higher (1.72 g/L). Illicit drugs (mainly amphetamine and cannabis) were identified in ~7% of victims, either alone (2.5%), together with alcohol (1.8%) or a prescription drug (2%). The psychoactive prescription drugs identified were mainly benzodiazepines, z-hypnotics and tramadol, which were found in the blood of 7.6% of crash victims. ***Conclusions***: **The high median BAC in fatally-injured drivers speaks strongly towards alcohol-induced impairment as being responsible for the crash. Compared with alcohol, the prevalence of illicit and psychoactive prescription drugs was fairly low despite a dramatic increase in the number of drug-impaired drivers arrested by the police after a zero-tolerance law was introduced in 1999**.

Key Words: *Alcohol, driving, drugs, impairment, traffic fatalities*

Introduction

Driving under the influence of alcohol and/or other psychoactive drugs represents a major risk factor for traffic safety, because impaired drivers are over-represented in road-traffic crashes [1]. Efforts to deter drunken driving have a long history as evidenced by enforcement of statutory blood-alcohol concentration (BAC) limits of 0.20, 0.50 or 0.80 g/L (20, 50 or 80 mg/100 mL) in most nations. The differences in BAC limits between countries seems to depend more on political forces rather than traffic safety research [2].

The problem posed by driving under the influence of drugs (DUID) other than alcohol has led to the introduction of zero-tolerance laws for driving under the influence of controlled (scheduled) substances [3,4]. People use recreational illicit drugs to experience euphoria, to make themselves more extrovert or daring and such things are unacceptable when skilled tasks, such as driving, are performed [5]. Many psychoactive prescription drugs can impair cognitive and psychomotor functioning, which represents another problem for traffic safety [6]. Some pharmaceutical substances are also subject to abuse, as exemplified by an upsurge in use of pain medication, such as oxycodone and methadone, in some countries [7] and benzodiazepine sedatives have a long history of abuse [8].

After a zero-tolerance DUID law came into force in Sweden in 1999, the number of blood samples submitted by the police for toxicological analysis increased appreciably and is now 10–12 times higher than before the new law [9]. This apparent increase in the number of drug-impaired drivers on the roads in Sweden raises the question of whether use of illicit and psychoactive prescription drugs is also more prevalent in blood of drivers killed in road-traffic crashes.

In this retrospective study, we evaluated forensic toxicology reports of drivers killed in traffic crashes in Sweden between 2008 and 2011. The findings are robust because over 95% of fatally injured drivers are subjected to a forensic autopsy, which includes toxicological analysis of alcohol and other drugs in femoral blood samples.

Materials and methods

Forensic autopsies

Sweden has a population of ~9.4 million and forensic autopsies are performed at six university teaching hospitals throughout the country. A forensic autopsy is generally ordered by the police authorities when an out-of-hospital or suspicious death is investigated and this includes road-traffic fatalities. If a driver survives the crash and dies several days later in hospital then under these circumstances a post-mortem examination and associated toxicology is usually not required. The statutory blood-alcohol limit for driving in Sweden is 0.20 g/L (drunken driving) and there is also a more serious offence (aggravated drunken driving) at a BAC of 1.0 g/L. Driving with an illicit drug in blood was prohibited in 1999 and this legislation also covered scheduled prescription drugs if these were not being used in accordance with a physician's instructions.

Age and gender of the drivers killed along with the toxicological results from analysis of autopsy blood samples were entered into a database (TOXBASE). The victims of traffic crashes were identified from their 10-digit personal ID number obtained from the relevant road-safety authorities. None of the victims were identified by their name or address or other personal information. The forensic autopsy and toxicology reports were scrutinized for all drivers killed in road-traffic crashes between 2008 and 2011.

Well-standardized procedures are used to sample body fluids for toxicological analysis and the forensic pathologists always try to take femoral blood, bladder urine and vitreous humor from each corpse. These specimens contain potassium fluoride (1%–2%, v/v) as a preservative and enzyme inhibitor and are shipped refrigerated (4°C) to a central laboratory for analysis.

Toxicological analysis

The toxicological analysis of drugs and various drug metabolites begins with a broad immunological screening on urine samples if available otherwise on blood after precipitation of proteins. Enzyme immunoassay methods (EMIT/CEDIA) are targeted at five major classes of abused drugs (opiates, amphetamines, cocaine metabolite, cannabis and benzodiazepines). Positive results from screening are always verified by more specific methods such as gas chromatography- mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS) with deuterium labelled internal standards.

Use of cannabis or marijuana is verified by analysis of THC in blood at a limit of quantitation (LOQ) of 0.0003 mg/L, whereas the corresponding LOQ for amphetamine and methamphetamine is 0.03 mg/L compared with 0.005 mg/L for morphine, codeine and 6-acetyl morphine. Prescription drugs (basic and neutral) are determined in blood by capillary column gas chromatography with a nitrogen-phosphorus detector. This analytical method permits quantitative analysis of approximately 200 different substances and some of the cut-off concentrations for reporting positives are 0.05 mg/L for diazepam and nordiazepam, 0.005 mg/L for flunitrazepam, 0.02 mg/L for oxazepam, 0.03 mg/L for zolpidem and 0.02 mg/L for zopiclone. The cut-off concentration for caffeine in blood was set high (10 mg/L) to avoid reporting positive results after drinking coffee, tea or soft drinks. When a general or local anaesthetic was identified in blood (e.g. ketamine, lidocaine, thiopental, etc.) the hospital records were reviewed to see if victims received these agents during emergency life-saving treatment.

The concentration of ethanol in blood was determined by a well established method based on head-space gas chromatography (HS-GC). Aliquots of blood (0.1 mL) were diluted 1+10 with t-butanol (0.05 g/L) as an internal standard, transferred into glass vials (22 mL) and made airtight with a rubber stopper and a crimped-on aluminium cap. All determinations of ethanol were done in duplicate on two chromatographic systems and the mean concentration reported. The HS-GC method has a limit of quantitation of 0.1 g/L in routine use although in the present study, the threshold for reporting alcohol positive cases was raised to 0.20 g/L, which is the statutory BAC limit for driving in Sweden. When femoral blood was unavailable, such as after massive trauma to the body, heart blood or blood from other sampling sites was analyzed. The results from 28 cases with BAC positive were not included in calculation of descriptive statistics because femoral blood was not available for analysis.

Table I.   Demographics of drivers killed in road-traffic crashes in Sweden 2008–2011.

Year	Fatalities N (%)	Females		Males	
		N (%)	Mean age (SD)[a]	N (%)	Mean age (SD)[a]
2008	264 (30)	41 (16)	51 (20.9)	223 (84)	46 (20.5)
2009	237 (27)	31 (13)	49 (21.9)	206 (87)	45 (19.9)
2010	200 (22)	28 (14)	52 (18.4)	172 (86)	45 (19.3)
2011	194 (22)	25 (13)	46 (21.3)	169 (87)	47 (18.6)
2008–2011	895 (100)	125 (14)	50 (20.6)	770 (86)[b]	46 (19.6)[c]

[a]SD = standard deviation. [b]More male than female drivers killed in traffic crashes ($p < .001$). [c]Mean age of male drivers was lower than females ($p < .05$).

Table II.   Prevalence of alcohol use by drivers killed in road traffic crashes in Sweden 2008–2011 and the concentrations in blood above the statutory limit for driving (BAC > 0.2 g/L).

Year	Fatalities N (%)	Alcohol Positive N[a] (%)	Blood-alcohol concentration, g/L Mean (median) range[b]
2008	264 (30)	49 (19)	1.60 (1.64) 0.21–3.23
2009	237 (27)	59 (25)	1.74 (1.74) 0.28–3.05
2010	200 (22)	31 (16)	1.97 (2.07) 0.32–2.94
2011	194 (22)	47 (24)	1.45 (1.50) 0.23–2.65
2008–2011	895 (100)	186 (21)	1.67 (1.72) 0.21–3.23

[a]All positive cases regardless of sampling site for obtaining blood. [b]Descriptive statistics for blood-alcohol concentration are for analysis of femoral blood (N = 158 cases).

Results

Demographics of traffic fatalities

Table I shows a clear predominance of male driver fatalities (86%) compared with female (14%) ($p < .001$). The mean age of all victims was 48 ± 20 years and males were 4 years older (50 ± 21 years) than females (46 ± 20 years) ($p < .05$). The vast majority of crashes involved drivers of private cars, N = 595 (66%), followed by motorcycles, N = 179, (20 %), drivers of commercial vehicles (trucks), N = 43 (4.8%), and the remainder were tractors, snowmobiles or mopeds etc (3.9%).

The mean age of victims depended in part on the toxicological findings. Drivers whose blood samples were negative for alcohol and/or drugs were significantly older (47 ± 20 years) compared with alcohol positive cases (35 ± 14 years) and those taking illicit drugs (34 ± 15 years) ($p < .001$). Fatally injured drivers with only medicinal drugs in blood were the eldest (56 ± 19 years).

Blood alcohol concentrations

The percentage of driver fatalities with BAC above the statutory alcohol limit (0.2 g/L) varied from 16%–25% (mean 21%) over the 4-year study period (Table II). The corresponding percentage of drivers with BAC above 0.50 g/L, 0.80 g/L and 1.0 g/L were
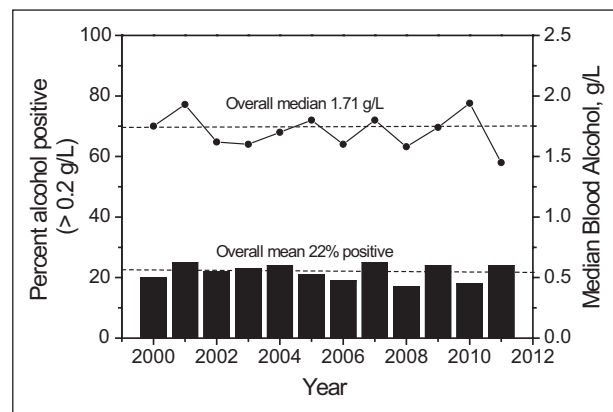

Figure 1.   Consolidated graph (2000–2011) showing percentages of drivers killed in road-traffic crashes in Sweden with blood-alcohol concentration (BAC) above the statutory limit for driving (0.2 g/L). Also shown is median BAC in the same fatalities.

19%, 17% and 16%, respectively. The mean BAC varied from 1.45 g/L (2011) to 1.97 g/L (2010) and 50% of drivers had a BAC between 1.5 and 2.5 g/L.

Figure 1 is a consolidated graph showing percentage of drivers with BAC above the legal limit as well as the median BAC for three study periods 2000–2002 [10], 2003–2007 [11] and 2008–2011. Over the 12 consecutive years, the results were remarkably consistent showing that 20%–22% of the drivers killed had been drinking and their BAC exceeded the legal limit. Median BAC in these fatally injured

Table III. Toxicological results from analysis of alcohol and/or other drugs in blood from drivers killed in road-traffic crashes in Sweden (2008–2011) in relation to mean age of victims.

Toxicology results	N (%)	Age (years) Mean (SD) range
Negative for alcohol and drugs	504 (56)	47[a] (20) 11–93
Alcohol only	131 (15)	35 (14) 13–74
Alcohol + illicit drugs	16 (1.8)	36 (14) 21–65
Alcohol + licit drugs	31 (3.5)	43 (19) 17–80
Alcohol + licit + illicit drugs	8 (0.9)	31 (10) 19–48
Illicit drugs only	22 (2.5)	34 (15) 14–63
Licit drugs only[b]	165 (18.4)	56 (19)[c] 16–91
Licit + illicit drugs	18 (2.0)	39 (15) 18–67
All cases	895 (100)	48 (20) 11–93

[a]Victims negative for alcohol and/or drugs were older (*p* < .01). [b]Many cases positive for non-scheduled drugs, such as paracetamol or SSRI antidepressants. [c]Mean age of victims positive for licit drugs was higher than all the other age groups (*p* < .01).

drivers was 8–9 times higher (1.6–1.8 g/L) than the legal alcohol limit in Sweden.

When examining the types of vehicles involved in fatal crashes, we found that 108 (18%) were private cars, 40 were drivers of motorcycles (22%), whereas alcohol was positive in only two drivers of commercial vehicles (5%). On the other hand, drinking drivers were over-represented in snowmobile and/or crashes involving mopeds (data not shown). Most fatally injured drivers were aged 15–60 years (82%) although there was no significant correlation between driver's age and BAC (*r* = 0.07, *p* > .05).

Co-ingestion of alcohol and drugs

The evaluation of alcohol and/or drug positive cases in Table III shows that alcohol was the only drug identified in 131 cases (15%), alcohol and an illicit drug was found in 16 cases (1.8%) and in 31 cases (3.5%) alcohol and a licit drug was confirmed. Eight fatalities (0.9%) were positive for alcohol and both an illicit and illicit drug. Overall, this meant that there were 186 alcohol positive cases (21%) with or without co-ingestion of other drugs.

Illicit drugs

Illicit drugs, either alone or together with alcohol or a licit drug, were identified in 64 cases corresponding to 7% of all drivers killed. The use of illicit drugs, mainly amphetamine or cannabis, was more highly prevalent in people killed in crashes involving motorcycles (18%) compared with private cars (5%). None of the drivers of commercial vehicles had an illicit drug in blood samples, whereas 11% of those killed

Table IV. Top-10 drugs identified and concentrations determined in femoral blood from drivers killed in road traffic crashes in Sweden 2008–2011.

Drugs identified[a]	Positive cases, N		Blood concentration, mg/L Mean (median) highest[c]
	All[b]	Femoral[c]	
Alcohol	186	158	1670 (1720)[d] 3230
Paracetamol	71	58	12 (3) 200
THC[e]	31	24	0.005 (0.002) 0.046
Amphetamines	30	23	1.30 (0.79) 6.74
Citalopram	26	18	0.44 (0.45) 0.80
Sertraline	19	13	0.22 (0.20) 0.5
Tramadol	17	13	1.39 (0.20) 11.6
Diazepam	16	11	0.16 (0.10) 0.40
Zopiclone	14	10	0.16 (0.06) 0.60
Mirtazapine	13	9	0.17 (0.10) 0.40

[a]Alcohol and/or licit or illicit drugs were identified in some cases. [b]Positive cases regardless of the blood sampling site. [c]Descriptive statistics are concentrations of drugs determined in femoral blood. [d]Median BAC of 1720 mg/L is same as 1.72 g/L (0.172 g% or 172 mg/100 ml). [e]THC is tetrahydrocannabinol the active substance in cannabis/marijuana.

on mopeds had used some type of illegal recreational drug (data not shown).

The illicit drugs most frequently encountered in traffic crashes in Sweden were cannabis/marijuana (*N* = 31), amphetamines (*N* = 30) and cocaine (*N* = 8). The mean, median and highest concentrations of the top 10 drugs identified in femoral blood are shown in Table IV.

Pharmaceuticals

Medicinal drugs were identified in 165 traffic fatalities (18.4%), but most of these drug-positive cases were paracetamol (*N* = 58) or SSRI antidepressants (*N* = 31), which are substances not normally considered to represent a danger for traffic safety (Table IV). Potentially dangerous psychoactive drugs were dominated by sedative-hypnotics, such as diazepam (*N* = 16) and zopiclone (*N* = 14), although the concentration of the active substance in blood was mostly in the therapeutic range (Table IV). Pharmaceutical products listed as controlled substances in Sweden and considered dangerous to use by drivers were identified in blood samples from 68 fatally injured drivers (7.6%).

Discussion

Well known cross-cultural differences exist regarding use and abuse of alcohol and other drugs in society and this should be reflected in the prevalence and types of drugs identified in blood of traffic offenders. Not surprisingly, the legal drug alcohol topped the

list of psychoactive substances identified in blood samples from fatally injured drivers, which confirms results and surveys done in other nations [12]. The victims BAC exceeded Sweden's statutory alcohol limit for driving (0.2 g/L) in 21% of all fatalities, whereas the median BAC was more than 8 times higher (1.7 g/L). Indeed, in 76% of fatalities the autopsy BAC was over 1.0 g/L, which gives convincing evidence that these drivers were impaired at the time of the crash.

The most prominent illicit drugs identified in blood of drivers killed were THC, the active substance in cannabis/marijuana, and amphetamine, although prevalence of these substances was low compared with alcohol. Amphetamine has always been, and still is, a major drug of abuse in Sweden and other Nordic countries, including Finland [13], Denmark [14] and Norway [15]. The concentrations of amphetamine in blood in fatally injured drivers were high; mean (1.3 mg/L) and median (0.79 mg/L), which verifies intake of large amounts of the drug some time before the crash. The median concentration of THC (0.002 mg/L) in driver fatalities was higher than that found in non-crash drivers positive for cannabis/marijuana (median 0.001 mg/L) as reported in a previous study [16].

The concentrations of drugs determined in blood allows drawing conclusions about the likely pharmacologically effects on the individual and the potential for causing impairment of performance and behaviour [17]. Although the window for detection of drug use is wider for urine samples, a positive urine test for drugs does not necessarily mean a drug was still measurable in the driver's blood at the time of the crash. [18]. Results of urine analysis verifies prior intake of a drug but does not furnish useful information about effects of the drugs on the brain.

A definite strength of the present study is the high autopsy rate (> 95%) for drivers killed in traffic crashes, which makes this a population-based study of alcohol and drug involvement. The autopsy rates of drivers killed in crashes seems to differ widely from country to country and was only 50% in a recent Norwegian study [19]. The percentage of drivers killed in crashes in US states and subsequently autopsied was even lower, and also seemed to depend on the age and gender of crash victims [20]. The large amount of missing data in these US studies requires special statistical methods, such as "imputation procedures" to calculate the prevalence of alcohol and drug use by crash victims.

Ethanol was the psychoactive substance most often identified in blood samples although culpability for the crash was not further investigated. However, the fact that more than 50% of victims had a BAC above 1.5 g/L and 76% were over 1.0 g/L is convincing evidence that they were under the influence of alcohol at the time of the crash, which speaks towards driver culpability [21]. The present 4-year study (2008–2011) found that 21% of drivers had a BAC above the statutory alcohol limit and this result agrees very well with earlier studies, which gives additional confidence in the overall results [10,11].

The prevalence of alcohol use by fatally injured drivers in Sweden is appreciably less than in other nations, such as Australia [22] where 32.8% of drivers were above the legal limit of 0.5 g/L. In the US, 32% of drivers killed in crashes exceeded the statutory BAC limit of 0.8 g/L [23]. Making such cross-cultural comparisons is complicated because of different drinking habits and the fact that the statutory BAC limit differs four fold, being 0.2 g/L in Sweden and Norway, 0.5 g/L in Australia and 0.8 g/L in the US and the UK. Over the years 2008–2011, the present study found that 16% of drivers killed on the roads in Sweden had a BAC above 0.8 g/L, which is roughly half that in Australia and USA where higher BAC limits are enforced. In Norway 25% of fatally injured drivers were above a BAC limit of 0.2 g/L, which agrees well with data collected over 12 years in Sweden where 20%–22% of drivers were above this same BAC limit [19]. Epidemiological road-side surveys of drivers involved in traffic crashes show only small increases in risk between BAC of 0.2 to 0.5 g/L, but an appreciable increase in risk as BAC exceeds 0.8 g/L [24].

The prevalence of illicit drug use by drivers was 7% and this result agreed well with earlier years 2003–2008, despite a dramatic increase in number of drug-impaired drivers arrested [11]. Use of cannabis by drivers seems to be a minor problem in Sweden (3%) compared with many other nations, such as New Zealand, where 30% of drivers were for THC [25] or France where 29% aged under 30 years were positive [26]. When examining use of illicit drugs in relation to type of vehicle, motorcyclists had the highest percentage of positive findings (18%), and interestingly these individuals also had a higher frequency of previous arrests for illicit drug use and DUID (unpublished material).

The most common pharmaceutical drugs in blood of fatally injured drivers were paracetamol and SSRI antidepressants, although this type of medication is not considered a danger for traffic safety. The most prevalent psychoactive drugs were anti-anxiety agents (benzodiazepines), z-hypnotics or opioid analgesics. However, the concentrations of these substances were mostly within the therapeutic range, which suggests they might be incidental findings and not a causative factor in the crash. Interestingly, the

median blood concentration of tramadol was 0.32 mg/L when this was the only drug identified, compared with a much higher concentration of 1.39 mg/L when all positive cases were considered, including co-ingestion of alcohol or illicit drugs. Two drivers had very high concentration of tramadol in femoral blood (3.0 mg/L and 11.6 mg/L), which points towards abuse of this centrally-acting analgesic. The possibility that concentrations of some drugs in blood increase after death deserves consideration, especially basic drugs and those with large volumes of distribution [27]. This post-mortem artefact would mean that the ante-mortem or peri-mortem concentrations of drugs were in fact lower than the post-mortem concentrations reported in this manuscript.

A viable defence against the charge of driving under the influence of a scheduled pharmaceutical substance is having a valid prescription for the medication and that the concentration in blood is within the accepted therapeutic range [3]. However, an ongoing study found that only 26% of drivers with diazepam in blood had a prescription issued to them for this medication, so 84% of drivers had obtained the drug illegally (Tjäderborn, personal communication). According to the present study, the median concentration of diazepam in blood of fatally injured drivers was 0.10 mg/L, which is sub-therapeutic and much lower than the median concentration of 0.2 mg/L in apprehended drivers not involved in fatal crashes [28].

The high concentrations of some pharmaceuticals, e.g. citalopram 0.80 mg/L and metoprolol 2.2 mg/L, might suggest overdosing with the medication and some traffic crashes could be a concealed suicide attempt [29]. It is not advisable to calculate the dose of a drug from the concentration determined in post-mortem blood owing to post-mortem redistribution phenomena as mentioned above [27]. The time when the drug was taken is never known with certainty and people differ widely in their capacity to metabolize various drugs depending on their age and ethnicity. The cause or causes of a traffic crash are multi-factorial involving problems with the vehicle, speeding, passengers and other distractions, weather conditions, traffic intensity etc., and not least driver impairment from use of alcohol and/or other drugs.

Several studies have addressed the high recidivism rates among drunk and drugged drivers, which suggest that treatment for substance abuse might be more worthwhile than conventional use of fines or imprisonment [9,30]. The need for rehabilitation is supported by a search of our database, because we found that many of those drivers killed had previous arrests for drunk or drugged driving (unpublished results). Careful consideration of the underlying substance abuse problem, including education, psychological counselling and rehabilitation, might help to lower the risk of re-offending and improve traffic safety.

In conclusion, this study verifies that over-consumption of alcohol and drunkenness was much more common in fatally injured drivers compared with use of other drugs. Indeed, 76% of drivers killed in crashes had a BAC > 1.0 g/L. When alcohol use and crash statistics were consolidated over a 12-year period (Figure 1) the results were remarkably consistent showing 20%–22% of drivers above the statutory limit of 0.2 g/L. The median BAC was appreciably higher (1.7 g/L), which gives convincing evidence that the driver was impaired by alcohol at the time of the crash. The prevalence of illicit drug use was fairly low compared with over-consumption of alcohol. The psychoactive prescription drugs in blood of drivers were mainly benzodiazepine anxiolytics, pain-medication (tramadol) and sleeping-aids (z-hypnotics). However, the concentrations of many pharmaceutical substances were in the therapeutic range and their presence in blood is probably an incidental finding and not a direct contributor or cause of the crash.

Conflicts of interest

None declared.

Funding

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