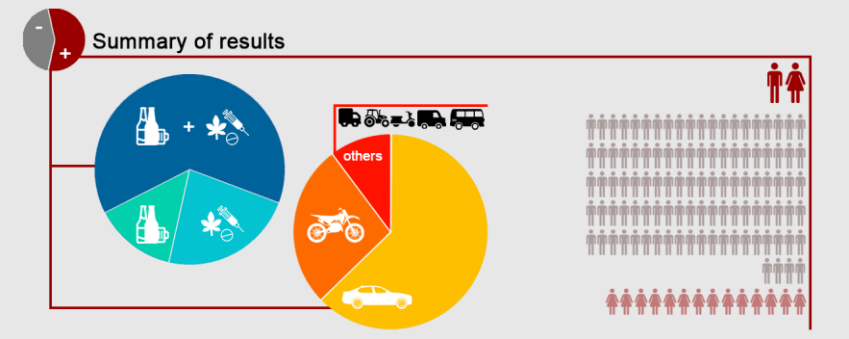
Toxicological findings in driver and motorcyclist fatalities in Scotland 2012–2015

Hilary J Hamnett,* Martha Ilett†, Fauzia Nurul Izzati, Shannah Smith‡ and Kirsty H Watson
Forensic Medicine & Science, University of Glasgow, Glasgow, G12 8QQ, UK

Graphical Abstract



Highlights

- The toxicological findings in driver and motorcycle fatalities in Scotland have been examined.
- Fifty-seven percent of the cases examined were positive for drugs and/or alcohol.
- The most common findings were alcohol and cannabinoids.

Abstract

Fatal motor vehicle crashes (MVCs) continue to be a common occurrence worldwide. This paper presents a retrospective analysis of the toxicological investigation of drivers and motorcyclists fatally injured in MVCs in Scotland from 2012 to 2015. One hundred and eighteen cases with full toxicological analysis, *i.e.*, alcohol, drugs of abuse and prescription drugs, were examined. Of those 118 MVC cases, 74 (63%) were car drivers, 32 (27%) were motorcyclists and the remaining were drivers of other vehicles such as large goods vehicles. The majority of deceased drivers and motorcyclists were male (N = 104, 88%). For the toxicological findings, 51 (43%) were negative, and of the 67 (57%) positive cases, alcohol and cannabinoids were the most frequently detected substances, followed by opiates and benzodiazepines. Fifteen percent of all drivers and motorcyclists were over the prescribed blood alcohol limit at the time of analysis. In comparison to previous reports

* Corresponding author: hilary.hamnett@glasgow.ac.uk
† Present address: Faculty of Engineering, University of Leeds, Leeds, LS2 9JT, UK.
‡ Present address: Centre for Anatomy & Human Identification, University of Dundee, Dundee, DD1 5EH, UK.

of drug use by drivers in Scotland, benzodiazepines and NPS were less common findings in fatally injured drivers and motorcyclists than in drivers suspected of being impaired.

Introduction

It has long been recognized that alcohol and certain drugs may impair a person's driving ability [1]. It is also well known that drug use by drivers can increase the risk of being killed in motor vehicle collisions (MVCs) [2-4]. Both illicit psychoactive drugs such as cannabis and amphetamine, and prescription medications such as benzodiazepines can impair driving [5].

Fatal MVCs continue to be a common occurrence worldwide, with the World Health Organisation reporting that 1.25 million road traffic deaths occurred globally in 2013 [6]. Surveys of the incidence of drugs and alcohol in MVCs have been carried out in numerous countries, including Australia [7], Brazil [8], Canada [1], England & Wales [9, 10], France [11], Jordan [12], New Zealand [13], Norway [14, 15], Spain [16], Sweden [17] and other Northern European Countries [18], and the USA [19]. However, little is known about how frequently drugs are involved in fatal MVCs in Scotland, with the last detailed study having been published in 1999, and then only for the Strathclyde region [20]. Updated information is required in order to reflect changes in the availability of new substances, and changes in drug use trends and legislation [9].

The Toxicology Laboratory based within Forensic Medicine & Science at the University of Glasgow receives post-mortem cases from all regions of Scotland with the exception of the far northern regions. All post-mortem cases submitted to the laboratory for toxicological investigations are recorded within the in-house database, which also incorporates some demographic information [21].

The aim of this study was to examine the toxicological findings in recently fatally injured drivers and motorcyclists in Scotland, and analyse them with respect to gender, age, vehicle type and drug and alcohol findings.

Method

Fatal MVC cases received by the laboratory between June 2012 and September 2015 involving deceased drivers and motorcyclists were selected for this study. Deceased cyclists, pedestrians and passengers were not included in the scope. One hundred and forty-six cases were identified from the cause of death entered in the in-house database (for West of Scotland cases) or from case documentation (for other areas of Scotland).

As part of routine casework for these fatalities when they were initially submitted, whole peripheral post-mortem blood samples were collected. Preserved blood samples were analysed for alcohol (GC-FID) and unpreserved blood samples were analysed for drugs of abuse (ELISA), paracetamol (HPLC) and basic drugs (GC-MS) as a minimum. The basic drugs analysis targets a range of prescription medications including antidepressants, antipsychotics, antihistamines and analgesics such as methadone. The core drug groups recommended in the guidelines for this type of study were all tested [22].

Presumptive ELISA positives were confirmed by more specific and sensitive mass spectrometric techniques (GC-MS and LC-MS/MS) on unpreserved blood samples, except for cocaine analyses, which were carried out on preserved blood. Urine and vitreous humour samples were available in some cases and were analysed for alcohol and, if applicable, opiates. However, findings in urine and vitreous humour are not reported in this study. Hospital samples were analysed in nine cases (N = 3 whole blood samples and N = 6 serum samples). In cases where emergency medical treatment was indicated in the case records, findings of morphine, ketamine, midazolam or lidocaine were excluded.

Results & Discussion

Of the 146 cases identified, only 118 had full toxicological results. In December 2014 the Scottish Government reduced the legal blood alcohol concentration (BAC) limit for drivers from 80 mg/100 mL to 50 mg/100 mL. Forty-nine of the cases examined in this study occurred after the new limit was introduced and 97 occurred before. A summary of the results of this study is shown in Table 1.

Case type (*N* = 118)	***N***	**%**
Negative	51	43
Alcohol-only positive (BAC ≥10 mg/100 mL)	9	8
Drug-only positive	43	36
Alcohol and drug positive	15	13
Car drivers	74	63
Motorcyclists	32	27
Other (LGV, minibus, van, tractor, scooter, quad bike)	12	10

Table 1. Summary of the cases examined.

Of the 118 cases examined, 88% of the drivers and motorcyclists were male, with only 12% of deceased drivers being female. All of the females in this study were car drivers. The mean age of female drivers (N = 14) was 44, range = 18–71, and the mean age of male drivers and motorcyclists

(*N* = 104) was 41, range = 17–86. The mean age for both genders was 41.5. The gender distribution for this study is shown in Figure 1.

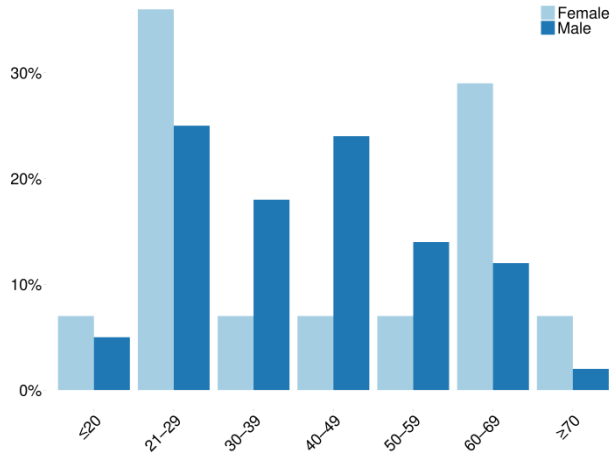


Figure 1. Age breakdown of fatal MVCs by gender.

In this study, 24 (20% of all fatalities) drivers or motorcyclists were positive for alcohol, with or without drugs. The BACs were characterised by a mean and median of 125 mg/100 mL with a range of 10–256 mg/100 mL. Of the 24 alcohol-positive drivers and motorcyclists, all but one were male, in agreement with previous research indicating that men in Scotland are more likely to drive after drinking than women [23].

It should be noted that five of the BACs reported in this study were <50 mg/100 mL (concentrations of 10, 10, 12, 24 and 38 mg/100 mL, all post-mortem samples) and that the interpretation of BACs in post-mortem cases can be complicated by post-mortem alcohol production. Upon decomposition, alcohol can be produced by the action of microbes and the fermentation of glucose [12]. This phenomenon can lead to BACs of up to 60 mg/100 mL [24]. Consequently, the presence of alcohol in the five cases mentioned above, could have been due to post-mortem production rather than any ante-mortem consumption of alcohol by the drivers.

Fifteen percent of all fatalities in this study (*N* = 18) involved a driver or motorcyclist who was over the prescribed blood alcohol limit at the time of analysis. This is lower than all of the similar studies reported in the literature, including the 21% in Sweden (limit = 20 mg/100 mL) [17], 11% in France (limit = 50 mg/100 mL) [11], 25% in Norway (limit = 20 mg/100 mL) [14], 36% in Brazil (zero tolerance) [8], and 29% in Australia (limit = 50 mg/100 mL) [7]. Of the alcohol-positive drivers, 75% were over the prescribed limit at the time of analysis in this study, compared to 67% in a study in England & Wales (limit = 80 mg/100 mL) [9].

Across the three-year period examined, data showed the use of drugs alone increased, while the use of a combination of drugs and alcohol decreased. Only 4 cases were examined from 2012, so these cases are excluded for this comparison only to leave 114 cases with full toxicological data. The number of cases involving drug use alone in fatal driver MVCs from January–December 2013 was found to be 11 (38% of the year's cases), 10 in 2014 (25%) and 21 in 2015 (47%); it must be noted that the data for 2015 is incomplete. Alcohol and drug use were found in 14% (*N* = 4) of fatal driver MVCs in 2013, 10% in 2014 (*N* = 4) and 13.3% in 2015 (*N* = 6).

To simplify the statistical analysis, drugs were categorized into drug families [10]. *Benzodiazepines* includes diazepam and its active metabolites desmethyldiazepam, temazepam and oxazepam, and the new-generation benzodiazepine phenazepam. The *cannabinoid* group contains only the active ingredient, Δ^9-tetrahydrocannabinol (THC), and/or its carboxy metabolite (carboxy-THC); synthetic cannabinoid compounds were not included in this study. *Opioids* includes codeine, morphine, dihydrocodeine, tramadol and methadone. These opioids were part of the 'opiates' or 'basic drugs' analyses. Other opioids, such as oxycodone, require specific targeted analyses, carried out on a case-by-case basis, and were not seen in this study. The drugs included in the *other prescription medications* group were antidepressants, antihistamines and anticonvulsants. The only non-prescription medications encountered were diphenhydramine and paracetamol, and these are categorized as *over-the-counter medications.* The final drug category was *stimulants* and encompassed cocaine and/or its metabolites benzoylecgonine, ecgonine methyl ester and cocaethylene, and the amphetamine-type stimulants amphetamine, ephedrine and 3,4-methylenedioxymethamphetamine (MDMA, Ecstasy) with its main metabolite, 3,4-methylenedioxyamphetamine (MDA).
The most common drug finding in this study was cannabinoids (*N* = 24, 20% of all fatalities), with THC itself present in 8 of the 24 cases and always accompanied by carboxy-THC. Evidence of cannabis use was present in 10 cases in 2013 (34.5% of the year's cases), 7 cases in 2014 (17.5%) and 7 cases in 2015 (15.2%).

In studies concerning fatally injured drivers and motorcyclists from various countries, the incidence of drugs is variable, as is the range of drugs encountered. However, as in this case, cannabis use is often the most commonly detected, after alcohol. Comparison of cannabis prevalence with other studies in the literature is fraught with difficulties, with some analysing for THC only, others looking for a range of metabolites or other cannabinoids, and some papers not reporting their target analyte(s).

The percentage of cannabis positive cases in this study is higher than the 3% reported in Sweden (as THC) [17], 7% reported in France (as THC) [11] and 9.8% reported in the USA (analyte not stated) [25]. But lower than the 27% reported in Canada (as THC and/or carboxy-THC) [1] and 30% reported

in New Zealand (as THC) [13]. The high prevalence of cannabis use in these studies likely reflects the fact that cannabis is the most prevalent drug used across the UK and worldwide [10], although it was not detected at all in a study from Jordan [12], or in the earlier study of MVC fatalities in Scotland [20]. Cannabis (as carboxy-THC) was also the most common drug finding in deceased motorcyclists in a study in England & Wales [9].

It should be noted that cannabis metabolites persist for some time in the body before they are eliminated, and can therefore be detected long after any psychological effect or impairment has disappeared [26]. In addition, financial and time constraints imposed on some studies may mean that cannabis testing is prioritized, leading to an apparent increase in prevalence [24].

Following cannabinoids, the second most common drug finding was opioids (N = 16, 14% of all fatalities). Codeine accounted for the majority of findings (N = 9) followed by tramadol, methadone and morphine. Heroin use was confirmed in only one driver (car), verified by the presence of 6-monoacetylmorphine (6-AM) in the urine sample. However, some of the other morphine-positive cases might also have involved heroin use, but a longer survival time meant that the 6-AM metabolite was no longer measurable in blood or urine owing to its short elimination half-life [8].

The third most common drug finding was benzodiazepines (N = 14, 12% of all fatalities). Diazepam was found in 13 of the 14 cases, always with one or more active metabolite(s) and once with phenazepam. The final case was positive for phenazepam only [23]. Prescription details for each case were not always available, and there is an issue with abuse of illicit diazepam in Scotland [27], therefore it is not possible to determine if these findings represent legitimate therapeutic use, or illicit abuse of diazepam.

The use of diazepam generally increased over the period studied, with 4 cases identified in 2013, 2 cases in 2014, and 6 cases identified in 2015. Two phenazepam cases were identified in 2013 however its use was not seen again in MVCs included in this study. No other new-generation benzodiazepines were detected in this study.

Other prescription medications were the fourth most common finding in this study (N = 12, 10% of all fatalities) and included the antidepressants amitriptyline, mirtazapine and citalopram, the antihistamines chlorpheniramine and cyclizine, and the anticonvulsants gabapentin and valproic acid.

This was followed by over-the-counter medications (N = 10, 8% of all fatalities), with paracetamol accounting for 9 of the 10 cases. Paracetamol was found to show the greatest increase in use across

the three years, with only 1 case identified in 2013 (3.5% of the year's cases), 2 cases in 2014 (5% of the year's cases) and 6 cases identified in 2015 (13% of the year's cases).

Finally, stimulants were found in 10 of the cases examined (8% of all fatalities). Cocaine and/or its metabolites was detected in four cases (3% of all fatalities), with cocaine and cocaethylene detected only once, in the same case, accompanied by a BAC of 177 mg/100 mL. Amphetamine-type stimulants were detected in six cases (5% of all fatalities), with amphetamine itself accounting for half of the positives. Methamphetamine was not detected in this study.

In March 2015, new drug driving limits were introduced in England & Wales [28], which do not apply in Scotland. Table 2 shows the limits and a breakdown of the results of this study for comparison purposes. Note that the limits only apply to selected drugs encountered in this study.

Drug or metabolite	**New limit (µg/L)**	**Number positive**	**Number above the cut-off *N* (%)**
Benzoylecgonine	50	4	3 (75)
Cocaine	50	1	1 (100)
Diazepam[§]	500	13	9 (70)
MDMA	10	2	2 (100)
Methadone	500	3	2 (67)
Morphine	80	3	3 (100)
THC	2	8	8 (100)

Table 2. A breakdown of the results of this study compared to drug driving legislation in England & Wales.

Finally, the results of this study can be compared to previous reports of drug use by drivers in Scotland. In the study by Seymour and Oliver [20], the toxicological findings in 115 fatally injured drivers between 1995 and 1997 were examined. In that study, 45% of the cases were negative for both drugs and alcohol, compared to 43% in this study. However approximately one-third of all Seymour and Oliver's cases were positive for alcohol (mean BAC = 151 mg/100 mL, range = 10–233 mg/100 mL for 1997) compared to only one-fifth in this study. There was also a much lower incidence of drug use in the earlier study.

[§] The legislation also includes limits of 300 and 1000 µg/L for oxazepam and temazepam, respectively. The data in this study were not compared with these limits, as in each case the profile of results suggested that they were present as metabolites of diazepam.

In a 10-year review of drug use by living Scottish drivers from 1996–2008, ELISA was used to identify the presumptive presence or absence of drugs of abuse [29]. Figure 2 shows a comparison of the data from Officer [29] and the corresponding ELISA results from this study.

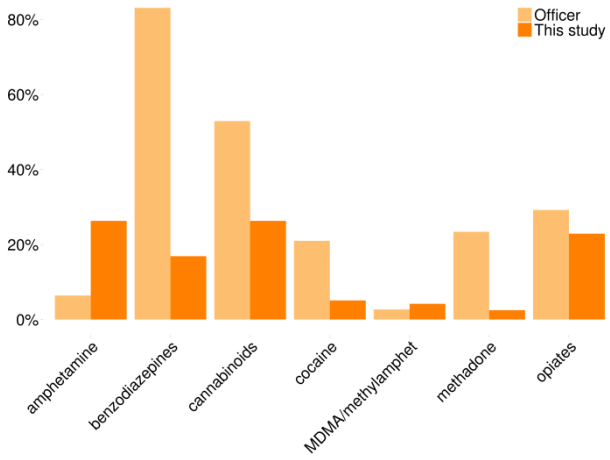


Figure 2. A comparison of the ELISA results for 2008 from Officer [29] with the ELISA results of this study.

It appears from Figure 2 that in living Scottish drivers, benzodiazepine use is more common than in deceased drivers and motorcyclists. However, it should be noted that the results in the paper by Officer [29] were not confirmed. It also appears from Figure 2 that amphetamine use is more common in deceased drivers and motorcyclists than in living drivers, however the number of confirmed amphetamine findings in this study was low (N = 6, 5% of all fatalities) indicating that the 26% amphetamine-positive ELISA results in this study represent mainly false-positives, a common occurrence in post-mortem toxicology. In a roadside survey of 386 oral fluid samples taken from non-accident-involved drivers in Glasgow during 2003–2004, stimulants (MDMA and cocaine) were the most common finding, followed by opiates [30].

Drivers suspected of being *impaired* (but not fatally injured) through the use of drugs in Scotland have demonstrated a high prevalence of new psychoactive substance (NPS) use, including cathinones, piperazines and new-generation benzodiazepines [31]. In this study, testing for NPS was not consistently carried out for all cases during the period 2012–2015.

The results of studies of fatal MVCs should be interpreted with caution; there can be a selection bias in the number of cases where autopsy and toxicological analysis are carried out [32], and also in the extent of toxicological testing. This is evident for MVCs in Scotland, where in a report of 115 MVCs during the period 2008 to 2009, 97% of the cases were tested for alcohol, but only 15% were tested for drugs [33]. In the present study, 100% of the cases were tested for alcohol and 81% were tested for drugs.

There are some limitations to this study. Firstly, the specimens tested were all from fatally injured drivers and motorcyclists, and hence there is no control group. Therefore, it is not possible to infer whether the incidence of drug use was higher among deceased drivers and motorcyclists compared with that of the general community [4]. Secondly, it should be noted that the presence of drugs in drivers does not necessarily mean that the drug was a causal factor in the MVC [26]. Indeed, some of the drugs detected in this study *e.g.*, paracetamol, are not known to produce driving impairment. The cause or causes of MVCs are multi-factorial, involving problems with the vehicle, speeding, passengers or other distractions, weather conditions and other traffic [5]. Information on whether the driver or motorcyclist was deemed responsible for the MVC following crash investigation, was not available in this study.

Conclusion

This study has reported the toxicological findings in fatally injured drivers and motorcyclists in Scotland from June 2012 to September 2015. Alcohol and cannabis were the most frequently encountered drugs, each with a prevalence of 20% of all fatalities, with 15% of all drivers and motorcyclists being over the prescribed blood alcohol limit at the time of analysis. The next most prevalent drug groups were opioids, benzodiazepines, other prescription and non-prescription medications, followed by stimulants. In comparison to previous reports of drug use by drivers in Scotland, benzodiazepines and NPS were less common findings in fatally injured drivers and motorcyclists than in drivers suspected of being impaired.

Future work will extend this study to fatally injured passengers, pedestrians and cyclists, and also focus on any differences in toxicological findings before and after the change in prescribed blood alcohol limit in Scotland.

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