Prevalence and Profile of Drugs and Alcohol in Fatally Injured Drivers in Pretoria, South Africa

Jade Liebenberg[1]
Department of Forensic Medicine, Faculty of Health Sciences, University of Pretoria, South Africa

Lorraine du Toit-Prinsloo
Department of Forensic Medicine, Faculty of Health Sciences, University of Pretoria, South Africa

Gert Saayman
Department of Forensic Medicine, Faculty of Health Sciences, University of Pretoria, South Africa

Vanessa Steenkamp
Department of Pharmacology, Faculty of Health Sciences, University of Pretoria, South Africa

ABSTRACT

South Africa (SA) is faced with continuing challenges pertaining to drug and alcohol abuse. Currently, there is a paucity of information regarding the involvement of non-alcohol substances in road-traffic accidents, as drugged-driving cases are seldom identified or prosecuted. The aim of this study was to establish the prevalence and profile of drug and alcohol use among drivers involved in fatal road accidents in Pretoria, SA.

[1] Please direct all correspondence to: Jade Liebenberg, Department of Forensic Medicine, University of Pretoria Private Bag X323, Arcadia 0007; Email: jadel92@hotmail.com

A one-year prospective analytical study was conducted at the Pretoria Medico-Legal Laboratory. Biological samples were collected at autopsy and drug-screening was conducted using immunoassay techniques, followed by liquid chromatography-tandem mass spectrometry confirmation. Blood-alcohol concentrations were determined using headspace gas chromatography with flame ionization detection.

The presence of one or more drugs of abuse was confirmed in 8% of fatally injured drivers (N = 112). The majority of drivers who tested positive for drugs or alcohol were males and younger than 40 years of age. Amphetamine-type stimulants were detected in 4.5% of cases, followed by opioids (3.6%) and cannabis (2.7%). Alcohol was detected in 57.5% of cases, and in combination with a drug(s) in 4.5% of cases.

Drugs were detected in approximately one in twelve drivers who were fatally injured in motor-vehicle accidents in Pretoria. Current practices for detecting driving under the influence in SA need to be reviewed and further research is necessary to better establish the extent of drug- and alcohol-impaired driving, in order to develop appropriate prevention strategies.

Keywords: Alcohol, drivers, drugs, fatal, South Africa

INTRODUCTION

Driving while intoxicated is a major risk factor for all types of road-traffic injuries. It is well known that alcohol causes significant impairment of driving performance and is a leading contributor to road-traffic fatalities of both vehicle occupants and pedestrians (WHO, 2018a). However, in recent decades a growing body of evidence has also linked non-alcohol substances (illicit and/or licit drugs) to poor driving performance and increased crash involvement or crash culpability (Asbridge, Hayden, & Cartwright, 2012; Bogstrand, Gjerde, Normann, Rossow, & Ekeberg, 2012; Brady & Li, 2013; Dassanayake, Michie, Carter, & Jones, 2011; Li et al., 2012).

South Africa (SA) has one of the poorest road safety records in the world. According to the World Health Organization's (WHO) 2018 Global Status Report on Road Safety (GSRRS), the road-traffic fatality rate for SA was estimated at 25.9 per 100,000 of the population, compared to the global average of 18.2 per 100,000 (WHO, 2018b). The Road Traffic Management Corporation documented 14,071 road traffic fatalities in SA in 2016, equating to approximately 38 deaths per day (RTMC, 2017). It has been reported that for every person killed in a road crash in SA, an average of three are seriously injured and nine others

slightly injured (Arrive Alive, 2015). The financial burden of these road-traffic accidents is estimated at 3.4% of SA's Gross Domestic Product and a cost of approximately 143 billion South African Rand to the state, communities and individuals annually (Labuschagne, 2016).

South Africa is faced with a major challenge pertaining to drug and alcohol abuse, with the largest illegal drug market in sub-Saharan Africa and substance-use patterns above the global norm (Geyer & Lombard, 2014; Peltzer, Ramlagan, Johnson, & Phaswana-Mafuya, 2010; the United Nations Office on Drugs and Crime/UNODC, 2002; WHO, 2018a). According to the WHO, the consumption of alcohol in SA is one of the highest in the world, with a total per capita alcohol intake (among those 15 years and older) of approximately 9.3 litres of pure alcohol per annum, in comparison to the global average of 6.4 litres (WHO, 2018a). With regard to drug use, there are limited reliable statistics available relating to the extent of drug abuse in SA, as no comprehensive population-based study has been conducted in recent years (Central Drug Authority/CDA, 2013). The available data suggests that cannabis is the most used illicit drug in SA and is used by an estimated 3.65% of the population (CDA, 2019). Other drugs frequently used include cocaine, amphetamine-type stimulants (ATS) and opioids (CDA, 2019). Methaqualone (Mandrax) continues to be widely used in SA, often in combination with cannabis (colloquially known as 'white pipe') and the street drug Nyaope or Whoonga (a low-grade mixture of heroin and cannabis) has also gained popularity in recent years (CDA, 2019; Harker et al., 2019).

Driving under the influence of drugs (DUID), also referred to as drugged driving, can be defined as being in control of a motor vehicle whilst under the influence of one or more psychoactive drugs (Holmes, Vanlaar, & Robertson, 2014). Several studies have reported that the intake of psychoactive drugs and/or a combination of two or more drugs may impair driving and increase the probability of a road-traffic accident (Drummer et al., 2004; Elvik, 2013; Gjerde, Strand, & Mørland, 2015). Frequently used drugs of abuse considered to elevate the risk of a road-traffic accident are drugs which act on the central nervous system, including cannabis; depressants such as opiates/opioids and benzodiazepines; and stimulants such as amphetamines, methamphetamines, 3,4-methylenedioxymethamphetamine (MDMA) and cocaine (Drummer et al., 2004; Drummer et al., 2012; Elvik, 2013; Gjerde et al., 2015). The central nervous system effects associated with impaired driving for depressants include drowsiness, slow reaction times, poor coordination and difficulty concentrating (amongst others). In contrast, stimulants may increase alertness, but have also been reported to cause increased risk-taking behaviour such as speeding and disregarding road signs or signals (Couper & Logan, 2004). There is much controversy about the effects of cannabis use on driving. However, several studies have reported that perceptual functions are affected, and that cognitive and psychomotor impairment is increased when used in high doses or in combination with alcohol (Couper,

& Logan, 2004; Hartman, & Huestis, 2013; Laddha, Saini, Sharma, & Garg, 2011). Results from published international drugged-driving studies have found drugs of abuse to be present in between 8.8% and 39.6% of fatally injured drivers (Ahlm, Björnstig, & Öström, 2009; Brady, & Li, 2014; Del Río, Gómez, Sancho, & Alvarez, 2002; Drummer et al., 2004; Drummer et al., 2003).

In SA, drugged driving is seldom actively investigated and/or identified and there is very limited published data relating to the involvement of drugs in road-traffic accidents. In order to reduce road-traffic accidents, appropriate legislation (among other measures) is necessary to prohibit driving under the influence (DUI) of intoxicating substances. In South African law, DUI is regulated by the National Road Traffic Act 93 of 1996 (NRTA), which sets the limits for breath and blood alcohol in drivers of vehicles. The legal limits are defined as 0.24 mg/1000 mL and 0.05 g/100 mL for breath and blood alcohol, respectively. Section 65, subsection 1 in Chapter XI of the NRTA states: "No person shall on a public road- (a) drive a vehicle; or (b) occupy the driver's seat of a motor vehicle the engine of which is running, while under the influence of intoxicating liquor or a drug having a narcotic effect." The specific wording of the Act raises substantial concern, as many impairing drugs of abuse are not classified as narcotic in nature (e.g. crystal methamphetamine or cannabis). The Act does not provide any further statutory restriction on drugged driving. While roadside breathalyser tests to detect alcohol are routinely performed, police and traffic officers are not specifically trained to recognise the effects of illicit or other drugs which may impair judgement and driving skills, or to perform roadside assessments with respect to the effects of such substances. Even when blood samples are collected for evidentiary testing in a laboratory, testing for substances other than alcohol is rarely performed.

Pretoria (falling within the City of Tshwane Metropolitan Region) is the administrative and executive capital of SA and is situated in Gauteng, the most populated province in the country (Lehohla, 2016). Gauteng has the highest incidence of road-traffic accidents in SA, with 2 700 fatalities recorded in 2016, of whom 24.3% were drivers (RTMC, 2017).

To the authors' knowledge, the prevalence of drug use in any portion of Pretoria's driving population has not previously been reported on. The aim of this study was thus to investigate the prevalence and profile of alcohol and common drugs of abuse in the body fluids of fatally injured drivers who were admitted to the Pretoria Medico-Legal Laboratory (PMLL) over a one-year period.

MATERIALS AND METHODS

STUDY POPULATION

A prospective study was conducted at the PMLL over a full one-year period (2015-2016). The PMLL serves the greater part of the City of Tshwane Metropolitan Municipality (ranked as the fifth largest municipality in SA), with a population of approximately 2.9 million, according to the 2011 census (Lehohla, 2012b). In South Africa, the Inquests Act (Act 58 of 1959) mandates that all alleged unnatural deaths undergo a post-mortem examination by a forensic medical practitioner. Therefore, all decedents involved in a fatal road accident and who were confirmed to be the driver of the vehicle at the time of the accident were included in the study. Drivers who survived for longer than 24 hours following the accident were excluded, due to the elimination of drugs and alcohol from the body over time. A total of 112 decedents admitted to the PMLL over the one-year period met the criteria above. Demographic data of the victims were collected, as well as the time and date of the accident and the vehicle type.

SAMPLE COLLECTION AND ANALYSES

Prior approval to carry out the study was obtained from the Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria (Protocol number 240/2015).

Blood samples were collected during autopsy by the attending forensic medical practitioner and sent to the Pretoria Forensic Chemistry Laboratory (FCL) for blood-alcohol-concentration (BAC) analysis (as per standard procedure at the PMLL). This is routine practice at the PMLL in cases where drivers are fatally injured in road-traffic accidents (due to the possible associated legal implications). Ethanol concentrations were determined using head space gas chromatography with flame ionization detection and a value equal to or above 0.01 g/100 mL was considered a positive result.

In addition to the above, further blood, urine (if available) and vitreous humour samples were collected for drug analysis and stored at 4°C. All biological samples were initially analysed using an immunoassay technique, followed by a confirmatory analysis using liquid chromatography-tandem mass spectrometry (LC-MS/MS). It is standard practice in forensic toxicology to confirm screening results using a second or confirmatory analytical technique such as liquid or gas chromatography coupled with mass spectrometry which offers high accuracy and sensitivity (Levine, 2020).

After the immunoassay analysis had been conducted, the remainder of the sample was stored at -20°C until confirmatory analysis. Qualitative analysis using LC-MS/MS was performed for nine drugs of abuse, including: morphine, oxycodone, hydrocodone, amphetamine, methamphetamine, 3,4-methylenedioxy-methamphetamine (MDMA), cannabis (11-nor-9-carboxy-delta-9-tetrahydrocannabinol), cocaine (benzoylecgonine) and heroin (specifically the metabolite 6-monoacetylmorphine). The cut-off concentrations for these drugs were as follows: 25 ng/mL for morphine, oxycodone and hydrocodone; 50 ng/mL for amphetamine, methamphetamine, MDMA and benzoylecgonine; and 10 ng/mL for 11-nor-9-carboxy-delta-9-tetrahydrocannabinol and 6-monoacetylmorphine.

The elimination half-lives and detection windows differ for various drugs and certain drugs may be detected for several days (or weeks in chronic users) after the last use, particularly in urine (Verstraete, 2004). Therefore, the presence of a drug in a biological sample does not necessarily imply that the driver was under the influence or impaired at the time of the accident.

STATISTICAL ANALYSIS

Data capturing was performed using Epi Info™ 7.1.5.2 and statistical analysis was performed using Stata® 14.2 and Microsoft® Excel 2010. The data analysis consisted of descriptive statistics (means, medians, ranges and standard deviations) to characterise the distribution of the data.

RESULTS

A total of 1897 autopsies were conducted at the PMLL over the one-year study period (between 2015 and 2016), of which 496 (26.1%) fatalities were due to road-traffic accidents (including motor-vehicle/motorcycle drivers, passengers, cyclists and pedestrians). Of these, a total of 112 cases (22.6%) were identified as fulfilling the inclusion criteria of a motor-vehicle driver who survived the accident for less than 24 hours.

BLOOD ALCOHOL

The findings for blood alcohol are presented in Table 1. Among the study population, blood-alcohol results were available in 106 (94.6%) cases, of which 61 (57.5%) tested positive for alcohol (≥ 0.01 g/100 mL) and 54 (50.9%) had a BAC above the legal limit (0.05 g/100mL). The average BAC obtained from the cases

which tested positive was 0.15 g/100 mL and the maximum BAC reported was 0.39 g/100 mL, almost eight times the legal limit.

Table 1: Blood alcohol results

Blood alcohol results	n	%	Mean BAC (g/100 mL)
Positive (BAC ≥ 0.01 g/100 mL)	61	57.5	0.15
Negative	45	42.5	n/a
Total	106	100	n/a
BAC ≥ 0.05 g/100 mL	54	50.9	0.17

Not applicable (n/a)

The age and gender distribution of the study population is provided in Table 2. Males accounted for the majority of the study population (91.1%), and a similar proportion was observed for alcohol-positive drivers (90.2%). The proportion of drivers testing positive for alcohol was greater for those aged between 20 and 40 years, compared to other age groups, which had more alcohol-negative drivers. Most accidents involving alcohol occurred on weekends (Friday to Sunday) and during night-time hours (between 18h00 and 05h59), whereas accidents that did not involve alcohol took place mostly on weekdays, during day-time hours (between 06h00 and 17h59).

Table 2: Demographic characteristics and accident timeframes

Demographic characteristic	Total cases (N = 112)	Alcohol negative cases (n = 45)	Alcohol positive cases (n = 61)	
Gender	**n (%)**	**n (%)**	**n (%)**	**Mean BAC (g/100 mL)**
Male	102 (91.1)	41 (91.1)	55 (90.2)	0.14
Female	10 (8.9)	4 (8.9)	6 (9.8)	0.20
Age category (in years)				
16-19	4 (3.6)	2 (4.4)	2 (3.3)	0.15
20-24	12 (10.7)	4 (8.9)	8 (13.1)	0.14
25-30	23 (20.5)	7 (15.6)	13 (21.3)	0.16
31-40	34 (30.4)	12 (26.7)	22 (36.1)	0.14

41-50	20 (17.9)	9 (20.0)	9 (14.8)	0.22
51-64	15 (13.4)	7 (15.6)	7 (11.5)	0.08
65-85	4 (3.6)	4 (8.9)	0 (0.0)	n/a
Time of day				
Day: 06:00 – 17:59	35 (31.2)	24 (53.3)	10 (16.4)	0.09
Night: 18:00 – 05:59	77 (68.8)	21 (46.7)	51 (83.6)	0.16
Day of the week				
Monday – Thursday	54 (48.2)	28 (62.2)	25 (41.0)	0.13
Friday - Sunday	58 (51.8)	17 (37.8)	36 (59.0)	0.16

Not applicable (n/a)

DRUGS OF ABUSE

The presence of one or more drugs of abuse were confirmed in fifteen of the 112 cases. However, in six of these cases the patient had been hospitalised, and was believed to have received medicinal substances, such as painkillers containing opioids. These cases were excluded since the specific drugs detected could be related to medical treatment history and no other illicit substances were confirmed. Thus, nine cases (8%) were considered to be bona fide DUID cases. The toxicology results for these cases are summarised in Table 3. Alcohol was detected in combination with one or more drugs of abuse in five (4.5%) of the 112 cases, with the mean BAC being 0.08 g/100 mL.

Table 3: Toxicology results obtained from LC-MS/MS confirmation and blood alcohol analysis

Case	**Drug findings**			**Alcohol findings**
	Blood	**Urine**	**Vitreous humour**	**BAC (g/100 mL)**
1	MOR THC-COOH	6-MAM HYDC MOR	MOR	0.00
2	MAMP	NS	NS	0.03
3	THC-COOH	-	-	0.11
4	THC-COOH	MAMP	-	0.04

		AMP THC-COOH		
5	HYDC	HYDC MOR	HYDC	0.00
6	-	MDMA	-	0.00
7	NS	AMP	AMP	0.16
8	HYDC	MOR HYDC	HYDC	0.00
9	AMP OXY HYDC	AMP MOR OXY HYDC	OXY HYDC	0.08

Negative result (-); No sample (NS)

3,4-Methylenedioxymethamphetamine (MDMA); 6-Monacetylmorphine (6-MAM); 11-nor-9-carboxy-Δ9-tetrahydrocannabinol (THC-COOH); Amphetamine (AMP); Hydrocodone (HYDC) Methamphetamine (MAMP); Morphine (MOR); Oxycodone (OXY)

Amphetamine-type stimulants (amphetamine, methamphetamine and MDMA) were present in five cases (4.5%), with amphetamine being detected in three. Opioids (morphine, hydrocodone, 6-MAM and oxycodone) were detected in four cases (3.6%), followed by cannabis in three cases (2.7%) (Figure 1). No positive results were obtained for cocaine.

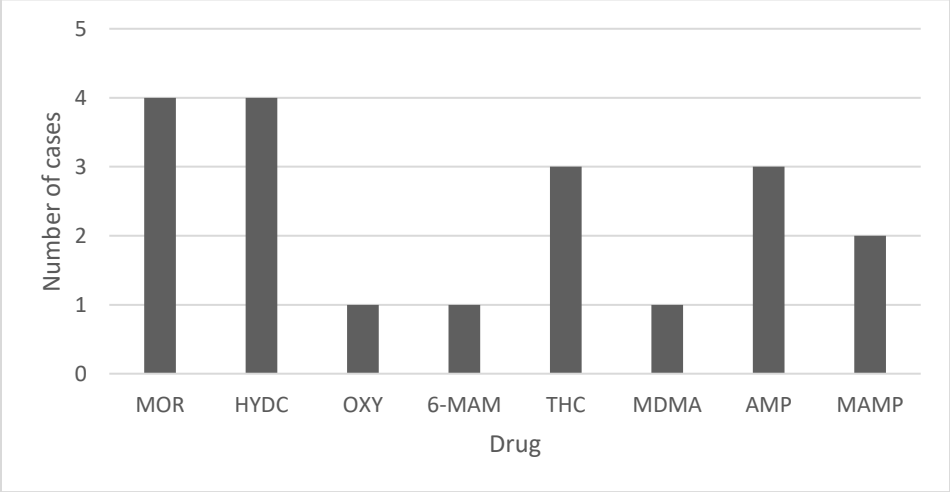

Figure 1: Frequency of different drugs detected by LC-MS/MS

Of the nine positive cases, the proportion of males who tested positive (88.9%) exceeded that of females (11.1%) and in five (55.6%) cases, the driver was younger than 40 years of age. In five of the nine positive cases the decedent was driving a passenger vehicle, in one case a motorcycle, and in one case a truck. Multiple-vehicle accidents (55.6%) were more prominent than single-vehicle accidents (11.1%), and in the majority of cases (55.6%) the accident occurred during daytime hours (between 06h00 and 17h59).

DISCUSSION

According to municipal and national statistics, males make up approximately 49% of the population (Lehohla, 2012a, 2012b). However, males accounted for 91.1% of fatally injured drivers during the study period. The greater proportion of male drivers involved in road-traffic accidents compared to women drivers is a consistent finding reported in various studies (Ahlm et al., 2009; Brady & Li, 2013; Del Río et al., 2002; Drummer et al., 2003; Drummer et al., 2012; Morland et al., 2011; Papa et al., 2017). The decedents involved in these accidents were also mostly young drivers. Males between the ages of 20 and 40 years comprised more than 50% of the fatally injured driver population at the PMLL. The higher incidence of young male drivers being involved in road-traffic accidents has also frequently been reported (Brady & Li, 2013; Del Río & Alvarez, 2000; Rudisill, Zhao, Abate, Coben, & Zhu, 2014; Walsh et al., 2005).

The prevalence of drivers testing positive for alcohol (57.5%) is in agreement with statistics reported in the 2018 GSRRS, which stated that 58% of road-traffic deaths in SA involved alcohol (based on 2010 National Injury Mortality Surveillance System data) (WHO, 2018b). The mean BAC obtained from the cases which tested positive (0.15 g/100 mL) also compares relatively well with a previous study conducted by Ehmke et al. (2014) at the PMLL, who reported that alcohol was present in 63% of fatally injured motor-vehicle drivers in 2009, with the mean BAC being 0.17 g/100mL (n = 119). In approximately half of the cases with alcohol results (50.9%), the BAC was above or equal to the South African statutory limit for driving (0.05 g/100 mL). This percentage is on the higher end in comparison with findings reported in epidemiological reviews from other countries, which found that 20 to 50% of drivers killed in road-traffic accidents had BACs above the statutory limit (Jones, 2017; Jones, Kugelberg, Holmgren, & Ahlner, 2009; Rudisill et al., 2014; Voas, Torres, Romano, & Lacey, 2012).

Fatal accidents involving alcohol mainly occurred on weekends (Friday to Sunday) and at night (18h00 to 05h59). The majority of cases which tested positive for alcohol were males (90.2%). This is in agreement with results obtained by Brady and Li (2014) and Petkovic, Palik, & Samojlik (2016), who reported that alcohol involvement was more prevalent in men. It has previously been reported that driving under the

influence is more common among young individuals (Kelly, Darke, & Ross, 2004; Li, Simons-Morton, & Hingson, 2013). In the current study 73.8% of the fatally injured drivers who tested positive for alcohol were ≤ 40 years, with the mean age being 34.7 years. Interestingly, the mean BAC detected in females was higher (0.20 g/100mL) than for males (0.14 g/100mL), and overall, the 41-to-50-year age group demonstrated the highest mean BAC of 0.22 g/100mL. Jones and Holmgren (2009) also found that middle-aged drivers (40 to 55 years) had the highest mean BAC among apprehended drivers in Sweden. The higher BAC observed in women drivers in this study may be attributed to the fact that women typically reach higher BACs, compared to men, when consuming the same amount of alcohol (Jones & Holmgren, 2009).

In the present study, 8% of fatally injured drivers tested positive for one or more drugs of abuse. This proportion is somewhat lower than was found in previous South African studies. A three-year study evaluated 1935 injured patients admitted to trauma facilities located in Cape Town, Durban and Port Elizabeth between 1999 and 2001. Of the patients with transport-related injuries (20.4% of total cases), 30.6% tested positive for urinary cannabis and 9.5% for white pipe (Marais, Sukhai, & Donson, 2004). A similar study was carried out in 2002 by Bowley et al. (2004), who examined 105 patients who had suffered traumatic injuries and were admitted to the Johannesburg Hospital Trauma Unit and the Johannesburg Medico-Legal Laboratory. Of the 22 cases where the injuries were due to motor vehicle-related trauma, 27.7% tested positive for urinary cannabis (Bowley et al., 2004). In a pilot study conducted by Matzopoulos et al. (2013) in 2008, drugs were detected in 14% of the drivers screened at roadblocks (N = 269). However, there are important differences between the above-mentioned studies: firstly, the study populations consisted mainly of living individuals and ante-mortem biological samples were analysed; secondly, different laboratory techniques were used to determine the presence of drugs; and thirdly, in the latter study, the individuals were tested at roadblocks where the time and place was controlled and targeted based on suspicion of persons DUI.

Studies conducted in Europe have reported between 8.8% and 18% of fatally injured drivers testing positive for drugs (illicit and/or licit) (Ahlm et al., 2009; Costa et al., 2012; Del Río & Alvarez, 2000; Del Río et al., 2002; Jones et al., 2009; Legrand et al., 2014; Morland et al., 2011). This percentage is reportedly higher in countries such as Australia (23.5%), and even greater in studies conducted in the USA, where between 24.6% and 31.8% of fatally injured drivers tested positive (Brady & Li, 2013, 2014; Drummer et al., 2003; Rudisill et al., 2014). The results from this study compare well with findings from other countries when keeping in mind that the current study only tested for a selected number of drugs of abuse, thereby overlooking certain drugs or drug classes that were included in the above-mentioned studies.

The higher proportion of young male drivers DUID, as seen in the current study, was expected and has been well documented in a number of studies (Davey, Armstrong, & Martin, 2014; Kelly et al., 2004; Rudisill et al., 2014; Schulze, Schumacher, Urmeew, & Auerbach, 2012). Unfortunately, the positive detection of only nine cases allows for limited interpretation of the related demographics and characteristics of these cases.

In international studies, the prevalence of illegal drugs among fatally injured drivers is variable, as is the frequency of the different substances detected. Still, several studies have reported similar findings indicating that stimulants, opioids, and cannabinoids are frequently detected substances among fatally injured drivers (Ahlm et al., 2009; Brady & Li, 2013, 2014; Costa et al., 2012; Del Río & Alvarez, 2000; Del Río et al., 2002; Drummer et al., 2003; Morland et al., 2011; Rudisill et al., 2014). It may be expected that the drugs detected among drivers are likely to reflect the general drug use trends observed in the particular community in which the study is performed. The low detection of cannabis (only present in three cases) is thus unexpected, since cannabis is alleged to be the most popular drug used in Gauteng (Nel, 2017). On the other hand, amphetamine-type stimulants featured more prominently compared to cannabis in a South African study conducted by Matzopoulos et al. (2013).

Drivers who are exposed to drug-drug or drug-alcohol combinations carry the highest risk of being involved in a road-traffic accident (Movig et al., 2004). The additive effects and greater impairment of psychomotor performance when alcohol is combined with other drugs have been demonstrated in previous studies (Doria, 1990; Drummer et al., 2004; Kelly et al., 2004). In this study, alcohol was detected in combination with one or more drugs of abuse in 4.5% of the total number of cases. The highest BAC recorded was 0.16 g/100 mL, in combination with amphetamine. Other drugs found in combination with alcohol included methamphetamine, cannabis, morphine, oxycodone and hydrocodone. In a large review of drivers killed in US traffic crashes between 1999 and 2010, Rudisill et al. (2014) reported that alcohol was detected in combination with other drugs in 45.3% of drug-positive cases (n = 23 500). Poly-drug-use (excluding drug-alcohol combinations) was evident in five (55.6%) of the nine cases in the current study. The combinations included heroin and cannabis; methamphetamine, amphetamine and cannabis; morphine and hydrocodone; and amphetamine and opioids. This is in keeping with reports that poly-drug-use is often detected in road-traffic injuries and fatalities. Studies have indicated that up to 20% of injured or killed drivers were under the influence of more than one substance at the time of the crash (Brady & Li, 2013; Callaghan et al., 2013; Jones et al., 2009; Movig et al., 2004).

As previously mentioned, the NRTA does not define the term ‘narcotic’. A comprehensive statutory definition thus needs to be formulated in a medical, legal and pharmacological context, to include other

classes of impairing drugs and identify the specific psychoactive substances prohibited by this law. Drug-driving legislation does, however, present with several complications in comparison to alcohol, due to the vast number of drugs available (each with unique pharmacological properties, effects and detection periods), and the limited evidence available demonstrating the relationship between drug concentrations and impairment. Internationally, some countries have taken the approach of passing *per se* laws for commonly abused drugs. *Per se* standards are generally classified into two types: zero-tolerance laws which prohibit driving under the influence of drugs at any detectable concentration, and *per se* laws which stipulate concentration limits for certain drugs or their metabolites (DuPont et al., 2012; Liebenberg, Du Toit-Prinsloo, Saayman, & Steenkamp, 2019). These laws make it illegal for drivers to operate a vehicle while having a detectable or specified concentration of a certain drug in their system, with no further evidence of impairment (or lack thereof) required.

Currently, there is a lack of standardised or routine drug screening for non-alcohol substances on randomly stopped drivers, or drivers who have been involved in accidents in SA. Drug screening is usually only requested on an *ad-hoc* basis when road-traffic authorities or medical practitioners have a particular reason to suspect that the driver may have been under the influence of drugs. This is mainly due to limited resources, backlogs at state laboratories causing long waiting periods for results, and a lack of statutory regulation. Ideally, the NRTA should make detailed provisions for drug-testing procedures on samples obtained at the roadside and in emergency rooms and mortuaries, and should specify the admissible medical evidence that would be required to prove or support a DUI offense. That being said, to adopt a standardised approach for the drug testing of drivers, it would be imperative to strengthen the laboratory testing capacity in SA (which is already strained) in order to accommodate for the increased caseload.

LIMITATIONS

Due to limited resources, it was possible to perform only qualitative confirmation for nine drugs of abuse. It is thus recommended that quantitative analyses be performed to determine specific drug concentrations and that additional drugs or drug classes, especially prescription medication, be included in future studies. Additionally, given the sample size of 112 drivers, the drug prevalence of only 8% allows for limited statistical inferences to be made regarding the characteristics of these cases. Results should therefore be interpreted with this in mind.

CONCLUSION

In this study, drugs were detected in approximately one in twelve drivers who were fatally injured in motor-vehicle accidents in Pretoria. Current practices for detecting driving under the influence of drugs in SA may be inadequate and under the existing legislation, law enforcement programmes and investigative procedures, very few cases of drug-driving are identified or pursued. Well-defined investigative protocols (for use by law-enforcement and healthcare professionals), as well as more efficient drug testing, could lead to significant improvements in the detection and successful prosecution of drugged drivers in SA. It is important for further research to be carried out and interventions such as random roadside testing and mandatory or routine testing of drivers involved in road-traffic accidents (including those fatally injured) should be considered in order to better establish the prevalence and profile of drug- and alcohol-impaired driving in SA.

ACKNOWLEDGEMENTS

The authors wish to thank Marga Kinnear from the Pretoria Forensic Chemistry Laboratory and Tracy Snyman from the Department of Chemical Pathology at the University of the Witwatersrand for their assistance with the toxicological analyses.

FUNDING

This work was supported by the National Research Foundation [grant number: 103058], the South African Medical Research Council (Self-Initiated Research Grant), and the Gauteng Department of Health.

REFERENCES

Ahlm, K., Björnstig, U., & Öström, M. (2009). Alcohol and drugs in fatally and non-fatally injured motor vehicle drivers in northern Sweden. *Accident Analysis & Prevention, 41*(1), 129-136.

Arrive Alive. (2015). *Decade of Action for Road Safety in SA: Mid-term report*. Retrieved from https://www.arrivealive.co.za/United-Nations-Decade-of-Action-for-Road-Safety-2011-2020

Asbridge, M., Hayden, J., & Cartwright, J. (2012). Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta analysis. *British Medical Journal, 344*, e536.

Bogstrand, S. T., Gjerde, H., Normann, P. T., Rossow, I., & Ekeberg, Ø. (2012). Alcohol, psychoactive substances and non-fatal road traffic accidents – a case-control study. *BMC Public Health, 12*(1), 1-9.

Bowley, D. M., Rein, P., Cherry, R., Vellema, J., Snyman, T., & Boffard, K. D. (2004). Substance abuse and major trauma in Johannesburg. *South African Journal of Surgery, 42*(1), 7-10.

Brady, J. E., & Li, G. (2013). Prevalence of alcohol and other drugs in fatally injured drivers. *Addiction, 108*(1), 104-114.

Brady, J. E., & Li, G. (2014). Trends in alcohol and other drugs detected in fatally injured drivers in the United States, 1999–2010. *American Journal of Epidemiology, 179*(6), 692-699.

Callaghan, R. C., Gatley, J. M., Veldhuizen, S., Lev-Ran, S., Mann, R., & Asbridge, M. (2013). Alcohol- or drug-use disorders and motor vehicle accident mortality: A retrospective cohort study. *Accident Analysis & Prevention, 53*, 149-155.

Central Drug Authority (CDA). (2013). *National Drug Master Plan 2013-2017*. Pretoria, South Africa: Department of Social Development. Retrieved from https://extranet.who.int/ncdccs/Data/ZAF_B10_National%20drug%20masterplan.pdf

Central Drug Authority (CDA). (2019). *National Drug Master Plan 2019-2024*. Pretoria, South Africa: Department of Social Development. Retrieved from https://www.gov.za/sites/default/files/gcis_document/202006/drug-master-plan.pdf

Costa, N., Silva, R., Mendonca, M. C., Real, F. C., Vieira, D. N., & Teixeira, H. M. (2012). Prevalence of ethanol and illicit drugs in road traffic accidents in the centre of Portugal: An eighteen-year update. *Forensic Science International, 216*(1-3), 37-43.

Couper, F. J., & Logan, B. K. (2004). *Drugs and human performance fact sheets. DOT HS 809 725.* Washington, DC: National Highway Traffic Safety Administration. Retrieved from https://www.wsp.wa.gov/breathtest/docs/webdms/DRE_Forms/Publications/drug/Human_Performance_Drug_Fact_Sheets-NHTSA.pdf

Dassanayake, T., Michie, P., Carter, G., & Jones, A. (2011). Effects of benzodiazepines, antidepressants and opioids on driving: a systematic review and meta-analysis of epidemiological and experimental evidence. *Drug Safety, 34*(2), 125-156.

Davey, J., Armstrong, K., & Martin, P. (2014). Results of the Queensland 2007-2012 roadside drug testing program: The prevalence of three illicit drugs. *Accident Analysis & Prevention, 65*, 11-17.

Del Río, M., & Alvarez, F. (2000). Presence of illegal drugs in drivers involved in fatal road traffic accidents in Spain. *Drug and Alcohol Dependence, 57*(3), 177-182.

Del Río, M., Gómez, J., Sancho, M., & Alvarez, F. J. (2002). Alcohol, illicit drugs and medicinal drugs in fatally injured drivers in Spain between 1991 and 2000. *Forensic Science International, 127*(1–2), 63-70.

Doria, J. (1990). Alcohol-drug interactions: perspectives on research and prevention. *Alcohol Health & Research World, 14*(1), 15.

Drummer, O. H., Gerostamoulos, J., Batziris, H., Chu, M., Caplehorn, J. R., Robertson, M. D., & Swann, P. (2003). The incidence of drugs in drivers killed in Australian road traffic crashes. *Forensic Science International, 134*(2-3), 154-162.

Drummer, O. H., Gerostamoulos, J., Batziris, H., Chu, M., Caplehorn, J., Robertson, M. D., & Swann, P. (2004). The involvement of drugs in drivers of motor vehicles killed in Australian road traffic crashes. *Accident Analysis & Prevention, 36*(2), 239-248.

Drummer, O. H., Kourtis, I., Beyer, J., Tayler, P., Boorman, M., & Gerostamoulos, D. (2012). The prevalence of drugs in injured drivers. *Forensic Science International, 215*, 14-17.

DuPont, R. L., Voas, R. B., Walsh, J. M., Shea, C., Talpins, S. K., & Neil, M. M. (2012). The need for drugged driving per se laws: a commentary. *Traffic Injury Prevention, 13*(1), 31-42.

Ehmke, U., Du Toit-Prinsloo, L., & Saayman, G. (2014). A retrospective analysis of alcohol in medico-legal autopsied deaths in Pretoria over a 1 year period. *Forensic Science International, 245*, 7-11.

Elvik, R. (2013). Risk of road accident associated with the use of drugs: A systematic review and meta-analysis of evidence from epidemiological studies. *Accident Analysis & Prevention, 60*, 254-267.

Geyer, S., & Lombard, A. (2014). A content analysis of the South African national drug master plan: Lessons for aligning policy with social development. *Social Work, 50*, 329-349.

Gjerde, H., Strand, M. C., & Mørland, J. (2015). Driving under the influence of non-alcohol drugs – An update. Part I: Epidemiological studies. *Forensic Science Review, 27*(2), 89-113.

Harker, N., Lucas, W., Laubscher, R., Dada, S., Parry, C., & Myers, B. (2019). *Opioid use treatment admission trends in South Africa 2012-2017: Implications for policy and practice.* SAMRC Alcohol, Tobacco and Other Drug Research Unit. Retrieved from

https://www.samrc.ac.za/sites/default/files/attachments/2020-01-28/Opioid%20treatment%20admission%20trends.pdf

Hartman, R. L., & Huestis, M. A. (2013). Cannabis effects on driving skills. *Clinical Chemistry, 59*(3), 478-492.

Holmes, E., Vanlaar, W., & Robertson, R. (2014). *The problem of youth drugged driving and approaches to prevention: A systematic literature review.* Ottawa, Ontario: Canadian Centre on Drug Abuse. Retrieved from http://www.ccsa.ca/Resource%20Library/CCSA-Youth-Drugged-Driving-technical-report-2014-en.pdf

Jones, A. W. (2017). Ethanol analysis in blood, breath and urine: Interpreting the results. In K. Wolff (Ed.), *Detection of drug misuse – Biomarkers, analytical advances and interpretation* (pp. 243-287). London, United Kingdom: Royal Society of Chemistry.

Jones, A. W., & Holmgren, A. (2009). Age and gender differences in blood-alcohol concentration in apprehended drivers in relation to the amounts of alcohol consumed. *Forensic Science International, 188*(1), 40-45.

Jones, A. W., Kugelberg, F. C., Holmgren, A., & Ahlner, J. (2009). Five-year update on the occurrence of alcohol and other drugs in blood samples from drivers killed in road-traffic crashes in Sweden. *Forensic Science International, 186*(1-3), 56-62.

Kelly, E., Darke, S., & Ross, J. (2004). A review of drug use and driving: epidemiology, impairment, risk factors and risk perceptions. *Drug and Alcohol Review, 23*(3), 319-344.

Labuschagne, F. J. J. (2016). *Costs of crashes in South Africa – Research and development report.* Road Traffic Management Corporation. Retrieved from http://www.rtmc.co.za/images/rtmc/docs/research_dev_rep/September%202016.pdf

Laddha, A., Saini, N. K., Sharma, P. K., & Garg, A. (2011). Drugs impairment on driving performance: An overview. *Pharmacologyonline, 1*, 737-747.

Legrand, S., Gjerde, H., Isalberti, C., Van der Linden, T., Lillsunde, P., Dias, M. J., . . . Verstraete, A. G. (2014). Prevalence of alcohol, illicit drugs and psychoactive medicines in killed drivers in four European countries. *International Journal of Injury Control and Safety Promotion, 21*(1), 17-28.

Lehohla, P. J. (2012a). *Census 2011 – Census in brief.* Pretoria, South Africa: Statistics South Africa. Retrieved from http://www.statssa.gov.za/census/census_2011/census_products/Census_2011_Census_in_brief.pdf

Lehohla, P. J. (2012b). *Census 2011 Municipal report – Gauteng.* Report No. 03-01-55. Pretoria, South Africa: Statistics South Africa. Retrieved from http://www.statssa.gov.za/census/census_2011/census_products/GP_Municipal_Report.pdf

Lehohla, P. J. (2016). *Mid-year population estimates.* Statistical release P0302. Pretoria, South Africa: Statistics South Africa. Retrieved from https://www.statssa.gov.za/publications/P0302/P03022016.pdf

Levine, B. S. (2020). Postmortem forensic toxicology. In B. S. Levine & S. Kerrigan (Eds.), *Principles of forensic toxicology* (5th ed., pp. 3-13). Switzerland: Springer.

Li, K., Simons-Morton, B., & Hingson, R. (2013). Impaired-driving prevalence among US high school students: Associations with substance use and risky driving behaviors. *American Journal of Public Health, 103*(11), e71-77.

Li, M., Brady, J., DiMaggio, C., Lusardi, A., Tzong, K., & Li, G. (2012). Marijuana use and motor vehicle crashes. *Epidemiologic Reviews, 34*(1), 65-72.

Liebenberg, J., Du Toit-Prinsloo, L., Saayman, G., & Steenkamp, V. (2019). Drugged driving in South Africa – an urgent need for review and reform. *South African Crime Quarterly, 67*, 7-18.

Marais, S., Sukhai, A., & Donson, H. (2004). Monitoring alcohol and other substance use in South Africa: The alcohol and drug injury nexus. In S. Suffla, A. van Niekerk, & N. Duncan (Eds.), *Crime, violence and injury prevention in South Africa: Developments and challenges* (pp. 128-144). Tygerberg, South Africa: Medical Research Council – University of South Africa Crime, Violence and Injury Lead Programme.

Matzopoulos, R., Lasarow, A., & Bowman, B. (2013). A field test of substance use screening devices as part of routine drunk-driving spot detection operating procedures in South Africa. *Accident Analysis & Prevention, 59*, 118-124.

Morland, J., Steentoft, A., Simonsen, K. W., Ojanpera, I., Vuori, E., Magnusdottir, K., . . . Christophersen, A. (2011). Drugs related to motor vehicle crashes in northern European countries: a study of fatally injured drivers. *Accident Analysis & Prevention, 43*(6), 1920-1926.

Movig, K. L., Mathijssen, M. P., Nagel, P. H., Van Egmond, T., De Gier, J. J., & Leufkens, H. G. (2004). Psychoactive substance use and the risk of motor vehicle accidents. *Accident Analysis & Prevention, 36*(4), 631-636.

National Road Traffic Act. See NRTA.

Nel, E. (2017). *Monitoring alcohol, tobacco and drug abuse treatment admissions in South Africa (Phase 40).* South African Community Epidemiology Network on Drug Use (SACENDU). Tygerberg, South Africa: South African Medical Research Council. Retrieved from http://196.21.144.194/adarg/sacendu/SACENDUPhase40.pdf

NRTA. National Road Traffic Act 93 of 1996. Retrieved from http://www.rtmc.co.za/images/rtmc/docs/legislation/National%20Road%20Traffic%20Act.pdf

Papa, P., Rocchi, L., Rolandi, L. M., Di Tuccio, M., Biffi, M., & Valli, A. (2017). Illicit drugs in emergency department patients injured in road traffic accidents. *Annali dell'Istituto Superiore di Sanità, 53*(1), 35-39.

Peltzer, K., Ramlagan, S., Johnson, B. D., & Phaswana-Mafuya, N. (2010). Illicit drug use and treatment in South Africa: a review. *Substance Use & Misuse, 45*(13), 2221-2243.

Petkovic, S., Palic, K., & Samojlik, I. (2016). Blood alcohol concentration in fatally injured drivers and the efficacy of alcohol policies of the new law on road traffic safety: A retrospective 10-year study in autonomous province of Vojvodina, Republic of Serbia. *Traffic Injury Prevention, 17*(6), 553-557.

Road Traffic Management Corporation (RTMC). (2017). *Road traffic report: 1 January - 31 December 2016*. Pretoria, South Africa: South African Department of Transport. Retrieved from http://www.rtmc.co.za/images/rtmc/docs/traffic_reports/calendar/Calender%202016%20report.pdf

RTMC. See Road Traffic Management Corporation.

Rudisill, T. M., Zhao, S., Abate, M. A., Coben, J. H., & Zhu, M. (2014). Trends in drug use among drivers killed in U.S. traffic crashes, 1999-2010. *Accident Analysis & Prevention, 70*, 178-187.

Schulze, H., Schumacher, M., Urmeew, R., & Auerbach, K. (2012). *Driving under the influence of drugs, alcohol and medicines (DRUID) Final Report: Work performed, main results and recommendations.* Deliverable 0.1.8. Bergisch Gladbach, Germany: Federal Highway Research Institute (BASt). Retrieved from http://www.druid-project.eu/Druid/EN/Dissemination/downloads_and_links/Final_Report.pdf?__blob=publicationFile&v=1

United Nations Office on Drugs and Crime (UNODC). (2002). *Country profile on drugs and crime – South Africa*. Pretoria, South Africa: UNODC. Retrieved from http://www.unodc.org/pdf/southafrica/country_profile_southafrica.pdf

UNODC. See United Nations Office on Drugs and Crime.

Verstraete, A. G. (2004). Detection times of drugs of abuse in blood, urine, and oral fluid. *Therapeutic Drug Monitoring, 26*(2), 200-205.

Voas, R. B., Torres, P., Romano, E., & Lacey, J. H. (2012). Alcohol-related risk of driver fatalities: An update using 2007 data. *Journal of Studies on Alcohol and Drugs, 73*(3), 341-350.

Walsh, J. M., Flegel, R., Atkins, R., Cangianelli, L. A., Cooper, C., Welsh, C., & Kerns, T. J. (2005). Drug and alcohol use among drivers admitted to a Level-1 trauma center. *Accident Analysis & Prevention, 37*(5), 894-901.

World Health Organization (WHO). (2018a). *Global status report on alcohol and health 2018*. Geneva, Switzerland: WHO. Retrieved from https://apps.who.int/iris/bitstream/handle/10665/274603/9789241565639-eng.pdf

World Health Organization (WHO). (2018b). *Global status report on road safety 2018*. Geneva, Switzerland: WHO. Retrieved from https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/