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Suspicion of driving under the influence of alcohol or drugs: Cross sectional analysis of drug prevalence in the context of the Swiss legislation strategy

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A B S T R A C T

Driving under the influence of alcohol and drugs (DUID) is a major field of study to improve road safety. In Switzerland, during controls whether or not they follow an accident, the police can request toxicological analysis targeted either on alcohol only (ALC cases), or on drugs and alcohol (DUID cases). To evaluate both the drugs consumption on the road and whether or not these requests are well correlated with toxicological results, we built a database recording 4003 offenders (3443 males, 550 females) over a two-year period (2018–2019) in Western Switzerland. ALC case samples were then analyzed to target other substances than ethanol. We found one or more psychoactive drugs in 89% of DUID cases and alcohol alone was found in 56% of ALC cases. In ALC cases, alcohol alone was found in 72% of non-accident cases and in 52% of accident cases. This highlights an influence of accident context, inducing a too high suspicion of alcohol after accidents, and therefore an underestimation of the prevalence of other drugs. The most frequently detected drugs in DUID cases were cannabinoids (58%), ethanol (30%), cocaine (21%), benzodiazepines (11%), amphetamines (7%), opiates (6%), and antidepressants (5%). For the ALC cases, the drugs found were ethanol (84%), cannabinoids (13%), benzodiazepines (9%), antidepressants (6%), opiates (5%), cocaine (4%), methadone (3%), and amphetamines (1%). Prescription drugs, such as benzodiazepines, were common in accidents (22%) but rare in non-accidents DUID cases (5%). Thus, these drugs highly impact driving skills while being hard to suspect. This is of first concern as prescription drugs are largely found in poly-drug consumption, especially in combination with alcohol in accident cases. This emphasizes the emerging issue of prescription drugs and should motivate a strategy of prevention focused on the noxious effect of combining alcohol and prescription drugs on driving skills.

1. Introduction

Driving under the influence of drugs (DUID) is a well-studied cause of impairment of driving skills. Indeed, psychoactive drugs may have an effect, among others, on reaction time, judgment and decision making, visual acuity, and drowsiness. Moreover, the use of drugs, and especially multiple drugs in combination, increases the risk and the gravity of road trauma [1–5].

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In Switzerland, the controlled substances and their punishable concentration threshold are established by the legislation, and the technical aspects are assured by the Federal Roads Office (FEDRO). At present, seven substances are listed in the zero-tolerance law, namely Δ-9-tetrahydrocannabinol (THC, major psychoactive constituent of cannabis), cocaine, free morphine (metabolite of heroin), amphetamine, methamphetamine, 3,4-methylenedioxymethamphetamine (MDMA or ecstasy), and 3,4-methylenedioxyethylamphetamine (MDEA). According to this legislation, the technical limits are 1.5 µg/L for THC and 15 µg/L for the other substances. In addition, the FEDRO establishes a ± 30% confidence interval for the measured value. Thus, the incapacity to drive resulting from the consumption of the previously mentioned drugs is confirmed with a blood concentration of respectively 2.2 and 22 µg/L. Concerning all the other psychoactive substances, the incapacity is evaluated after applying what is called the three pillar expertize, which relies on the evaluation of the impairment based on three different sources of information: the observations documented by the police during the control, the toxicological results, and the results of the clinical examination made at the time of sampling. Finally, the legal limits for blood alcohol concentration (BAC) are as follow: 0.5 g/kg (0.1 g/kg for new and professional drivers) defines drunken driving, and 0.8 g/kg defines aggravated drunken driving. In addition, a BAC above 1.6 g/kg leads to the evaluation of the driver's aptitude to drive. It is important to note that not all alcohol cases are sent to a laboratory, as a systematic control of alcohol in breath has been introduced. This breath control may be sufficient for prosecution, depending on the values obtained and the driver's cooperation.

As DUID is an important public health problem, we investigated the drivers' consumption of drugs in Western Switzerland. This was made in direct extension of several studies conducted in this country in the last 30 years [6–8] or at an international level [9–14]. That kind of longitudinal approach gives a unique opportunity to monitor the consumption habits over a large period, in terms of both type and concentration of drugs found, and thus highlights priorities in prevention and risk reduction.

A database was created including cases from cantons of Fribourg, Genève, Neuchâtel, Jura, Valais, and Vaud (Western Switzerland) spanning years 2018–2019. In order to have a broad vision on that consumption, this study did not focus only on cases where suspicion of DUID was made, but also on cases where alcohol was the only suspected reason explaining the toxicological analysis (ALC cases). This last category was analyzed a second time to detect the presence of potential drugs in addition to alcohol.

2. Material and methods

2.1. General

This study was realized in collaboration with the two main laboratories in Western Switzerland that have the authorization, given by the FEDRO, to perform toxicological analysis for the police. For the cantons of Fribourg, Genève, Neuchâtel, Jura, and Vaud, this laboratory is the Centre Universitaire Romand de Médecine Légale, and for the canton of Valais, it is the Institut Central des Hôpitaux du Valais. To ensure a uniform interpretation of the results and a correct analysis, the authorized laboratories have to participate in regular external quality control programs, organized by the Swiss Quality Control Center [15]. This leads to accurate results that can be compared.

All the biological samples used for this study were collected at hospital or police station by medical personnel, at the behest of the prosecutor. The delay between event and sampling was as short as possible and precisely recorded. Urine was taken depending on the case, while blood was taken in every case routinely. The blood collection was made in tubes containing potassium fluoride and EDTA as preservative and anticoagulant, respectively.

A database was created to collect the toxicological results. In addition, information from the police report and the medical report was gathered for each case. These data were anonymized, and each case entered in the database was automatically assigned a unique number. For each, the age, gender, date and time of the event, the type of vehicle, the sampling date and time, and the result of the breath alcohol test were collected. Furthermore, in each category, a separation was made between "Accident", including all cases following a road traffic accident, and "Non-accident" cases, including all cases following a police control with DUID suspicion motivated, among others, by an excessive speed, a dangerous or erratic driving, a traffic violation, or during random sobriety checks. It's noteworthy that there is no standardized procedure used by police to determine the impairment. Therefore, it relies only on the police officer appreciation of ability to drive, which can be helped by urinary or salivary screening.

Analyse-it V 5.0 (Analyse-it Software, Ltd.) combined with R Studio V 4.0.2 (RStudio, Inc.) were used to perform statistical analyzes. Mean, standard deviation, median, and percentiles 5, 25, 75, and 95 were used as descriptive statistics. Q-Q plots and Shapiro-Wilk test were used to assess the normality of the distributions. Differences between two populations were evaluated using a Kruskal-Wallis test for non-parametric data. Pearson's chi-squared test was used to compare two proportions. Finally, correlation between blood alcohol concentration and age was calculated using Spearman rank correlation coefficient. A 5% significance threshold was used to interpret the results.

2.2. Case selection

Two main categories were chosen to be included in this research.

1. Cases where alcohol and/or drugs were suspected by the police as the reason of the incapacitation to drive (DUID).
2. Cases where only alcohol was suspected by the police and asked to be analyzed by the laboratory (ALC).

Each case was assessed using four criteria, to determine if it could be included in the study or not: (1) the event took place between the 1st January 2018 and the 31st December 2019; (2) the submitted specimens were suitable for analysis; (3) the suspicion of driving under the influence of a substance was clearly indicated on the documentation associated with each sample; (4) the driver was alive at least 24 h after the sampling.

2.3. Toxicological analysis

For each case, the general analytical strategy was always the same. First of all, a broad screening was performed using immunoassays combined with gas chromatography-mass spectrometry (GC-MS) on urine, and high-resolution liquid chromatography-tandem mass spectrometry (LC-HRMS/MS) on blood [16]. To identify the peaks, GC-MS results were then compared to several databases: Maurer/Pfleger/Weber, Wiley, Designer Drugs, and National Institute of Standards and Technology (NIST). LC-HRMS/MS results were compared to mzCloud and an in-house database [PMID: 30967174] [16] (see Supplemental file for LOD/LLOQ of the main substances).

Every positive result after screening had to be confirmed and quantified in blood. Indeed, the detection of a particular xenobiotic is not sufficient to evaluate the impact of this substance on the driving skills. This was done by using more sensitive, and dedicated methods such as liquid chromatography-tandem mass spectrometry (LC-MS/MS) and GC-MS, depending on the targeted compound. The

Table 1
Incidence of gender, vehicle type, circumstances and age among 3287 drivers suspected of DUID and 716 drivers suspected of driving under the influence of alcohol only, between 2018 and 2019 in Western Switzerland.

Information	DUID (N = 3287)	ALC (N = 716)
Gender		
Male	2862 (87.1% of DUID cases)	581 (81.1% of ALC cases)
Female	415 (12.6% of DUID cases)	135 (18.9% of ALC cases)
Unknown	10 (0.3% of DUID cases)	0 (0.0% of ALC cases)
Vehicle type		
Car	2714 (82.6% of DUID cases)	446 (62.3% of ALC cases)
Motorcycle	288 (8.8% of DUID cases)	99 (13.8% of ALC cases)
Bicycle	87 (2.7% of DUID cases)	101 (14.1% of ALC cases)
Pedestrian	45 (1.4% of DUID cases)	31 (4.3% of ALC cases)
Truck	9 (0.3% of DUID cases)	2 (0.3% of ALC cases)
Other[a]	12 (0.4% of DUID cases)	7 (1.0% of ALC cases)
Unknown	132 (4.0% of DUID cases)	30 (4.2% of ALC cases)
Circumstances		
Accident	1034 (31.5% of DUID cases)	550 (76.8% of ALC cases)
Non-accident	2134 (64.9% of DUID cases)	131 (18.3% of ALC cases)
Unknown	119 (3.6% of DUID cases)	35 (4.9% of ALC cases)
Age		
Mean	34 (± 14 years)	45 (± 17 years)
Mode	21 years (n = 143)	40 years (n = 23)
Range	82 (13–95 years)	81 (16–97 years)

[a] Other regroups tractor, boat, bus, roller, and passenger.

result was considered positive if equal to or higher than the lower limit of quantification (LLOQ) of the dedicated analytical method used.

Alcohol was both qualified and quantified in blood using headspace gas chromatography coupled with flame ionization detector (HS-GC-FID).

Samples were stored from their collection to their analysis at − 20 °C or lower to avoid or slow down degradation. For the ALC cases, the quantification of other drugs than alcohol was made six months to two years after the sampling. This should be kept in mind because even if most analytes are stable when stored properly with preservative, cocaine and other molecules with ester moieties undergo a slow degradation over time [17]. Thus, their quantification in the ALC cases must be taken with some caution.

3. Results and discussion

3.1. Demographic of the offenders and circumstances

Over the two-year period of interest, 4003 cases (3287 DUID and 716 ALC) were selected for the present study. The main information is summarized in Table 1. As observed in other studies [6–14], there was a clear dominance of males in all populations. Nevertheless, the female proportion was influenced by circumstances, as it increased in the accident cases to 20.3% (N = 210) and 19.6% (N = 108) for DUID and ALC respectively while in the non-accident cases, it was 8.9% (N = 189) and 17.6% (N = 23) respectively.

In all categories, car drivers were largely predominant. However, an increase in the proportion of bikers was observed, which is consistent with the evolution of transportation habits [18]. As expected, the accidents involving bicycles are increasing in parallel with the augmentation of their use. However, their controls did not increase proportionally. Indeed, bicycles represented 7% (N = 72) of the DUID accident cases and 18% (N = 99) of the ALC accident cases, but only 0.7% (N = 14) and 1.5% (N = 2) of the non-accident cases. This suggests that the increase of bicycle use did not change the control strategy yet. Finally, the proportion of bicycles in the ALC cases was greater than in the DUID cases, suggesting that alcohol could be either more consumed by bicycle riders than other drugs, or more often suspected.

Interestingly, the predominant circumstances are not equal between the DUID and ALC population. For the DUID cases, the vast majority are non-accident (65%), whereas ALC cases are mostly accident (77%). This highlights that, after an accident, when a breath analyzer cannot be used, alcohol is more often suspected as the reason of driving impairment than other drugs.

Finally, the age of the drivers was reported in 3271 DUID cases and 715 ALC cases. The age distribution is presented in Fig. 1. DUID cases were composed of a young population mainly ranging from 20 to 40 years. Drivers of age 20–24 years were the most frequently represented (19%, N = 626). In contrast, the ALC distribution showed a much older population. Drivers of age 45–49 years and 25–29 years were the most represented (10%, N = 75 for both). In addition, men were younger in the DUID population (34 ± 14 years) than women (40 ± 16 years) (*Kruskal-Wallis test value = 63.1, p-value < 0.0001*). That was not the case for ALC population (45 ± 16 years and 46 ± 19 years respectively, *Kruskal-Wallis test value = 0.02, p-value = 0.8825*).

3.2. Main toxicological results

In the 3279 DUID and the 716 ALC samples on which toxicological analysis on blood were made, at least one psychoactive substance was found in 89% (N = 2916) and 92% (N = 661) respectively. Thus, only 11% of the DUID cases were drug-free, which can be considered as false positives. It's noteworthy that 68% (N = 247) of those drugs-free cases were consecutive to an accident. This is not surprising since accidents are events where it is difficult to evaluate drug-related impairment because of the driver's trauma and injuries. Therefore, the application of the Swiss legislation strategy allows good targeting on the toxicological positive DUID cases. The results are summarized in Table 2.

For the ALC cases, ethanol was found alone in 56% (N = 398) cases. The remaining 44% (N = 318) cases were composed of 8%

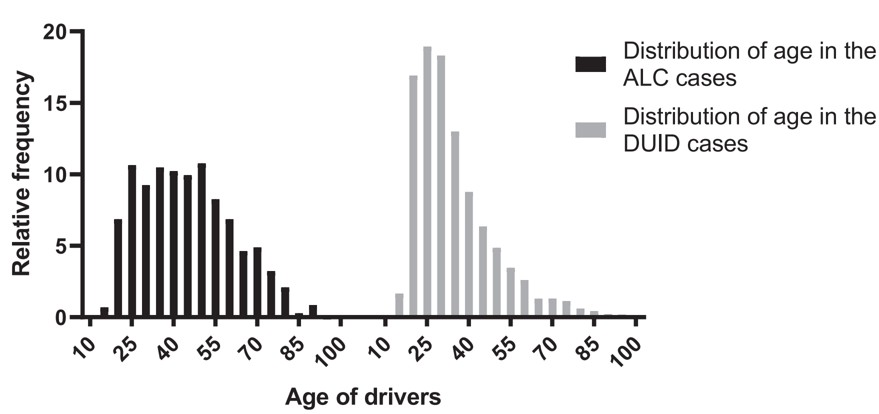

Fig. 1. Distribution of the relative frequencies of age in the 715 ACL cases and the 3271 DUID cases in which the age of the drivers was reported.

Table 2
Repartition of cases between drug-free, alcohol only, drugs only, and alcohol in combination with drugs, in the various circumstances of DUID and ALC cases on which toxicological analysis on blood were made.

	DUID (N = 3279)			ALC (N = 716)		
	Accident	*Non-accident*	*Total*	*Accident*	*Non-accident*	*Total*
Drugs-free	247	106	363	52	1	55
Alcohol only	159	61	234	286	95	398
Drugs only	295	1560	1924	55	1	59
Alcohol & drugs	331	401	758	157	34	204

(N = 55) drug-free cases, 8% (N = 59) involving drugs without alcohol, and 28% (N = 204) drugs in combination with alcohol. More significantly, a strong difference was observed between accident and non-accident ALC cases. Indeed, the proportion of those remaining cases was 48% (N = 264) for the accident cases, but only 27% (N = 36) for the non-accident ones. This highlights what we call the *influence of accident context*, which is the tendency, on the part of the police, to preferentially ask for the quantification of ethanol (and not other drugs) after an accident. This generates an underestimation of the prevalence of other substances in road accidents and may lead to an inaccurate interpretation of their cause. It then follows that, in non-accident ALC cases, the application of the Swiss legislation strategy allows a good targeting of positive toxicological results, but this is less the case in accident ALC cases.

However, it is important to keep in mind that most police controls do not involve toxicological analysis, because breath analyzers are often sufficient. Therefore, breath analyzers definitely cut the chain of evidence because a majority of cases never reach any toxicological laboratory. Thus, if the prevalence of drugs found is similar between ALC cases and cases in which only breath was analyzed, an important number of cases involving drugs other than alcohol must remain undetected.

For the DUID cases, the most frequently detected types of drugs were cannabinoids (58%, N = 1886), ethanol (30%, N = 992), cocaine (21%, N = 687), benzodiazepines (11%, N = 352), amphetamines (7%, N = 236), opiates (6%, N = 207), antidepressants (5%, N = 166), and methadone (3%, N = 83). Other psychoactive substances, mainly neuroleptics, were detected in less than 3% of all cases. Compared with past studies [6–8], opiates and methadone consumption has decreased, while cocaine and antidepressants consumption has increased. In addition, gender influenced the type of drugs found: benzodiazepines and antidepressants were more often detected in women (N = 108, 26%; N = 63, 15% respectively) than in men (N = 244, 9%; N = 102, 4%). In contrast, men were more often cannabinoid consumers (N = 1746, 61%) than women (N = 139, 34%). Finally, the

Table 3
Main toxicological results for the substances detected in the blood of 3279 drivers suspected of DUID in 2018 and 2019 in Western Switzerland. Results reported as total number of positive cases (N) (≥ LLOQ), mean, median, range and percentiles (p5, p25, p75, p95) of the concentrations (g/kg for ethanol, µg/L for others).

Substance	N	p5	p25	Median	p75	p95	Mean	Range
Cannabinoids								
THC	1580	1.3	2.5	4.6	8.4	18.0	6.6	1.0–52.0
THCCOOH	1731	7.1	16.0	31.0	53.0	120.0	43.2	5.0–440.0
11-OH-THC	1219	1.1	1.6	2.5	4.1	8.3	3.4	1.0–45
CBD	162	1.0	1.3	1.8	3.6	12.0	3.3	1.0–25.0
Ethanol	693	0.27	0.74	1.22	1.75	2.40	1.28	0.11–3.79
Cocaine								
Cocaine	374	12	23	49	100	300	88.5	10–1500
Benzoylecgonine	657	38	160	420	920	2300	678.8	20–5400
Methylecgonine	261	23	42	81	170	401	138.3	20–2000
Ethylcocaine	98	20	23	33	61	113	51.4	20–350
Amphetamines								
Amphetamine	142	14	32	71	168	543	146.5	11–1700
Methamphetamine	71	16	86	200	360	750	296.6	11–1000
MDMA	110	21	64	180	373	790	274.3	10–1400
MDEA	2	26	27	29	30	31	28.5	26–31
MDA	41	12	19	26	47	72	34.3	10–110
Opiates								
Free morphine	120	11	24	52	110	305	107.7	5–1625*
Free codeine	41	6	10	14	21	32	16.0	6–39
Methadone	66	27	66	125	220	425	164.2	14–630
EDDP	20	8	33	52	115	205	80.3	4–290
Benzodiazepines								
Alprazolam	36	4	19	39	61	218	67.3	3–630
Bromazepam	18	20	44	125	205	323	144.1	17–410
Clonazepam	16	5	9	20	51	86	34.1	4–104
Diazepam	32	11	38	95	215	783	223.4	4–1760
Lorazepam	62	5	12	25	39	88	34.4	3–290
Midazolam	41	8	13	28	62	253	65.6	3–520
Nordiazepam	56	22	51	200	483	1606	398.4	9–3200
Oxazepam	64	21	49	108	448	1187	321.1	20–2000
Antidepressants								
Citalopram	33	27	36	54	100	252	82.5	27–340
Clomipramine	10	9	14	30	60	139	48.5	5–170
Sertraline	6	113	121	138	210	245	164.2	110–250
Trazodone	11	350	400	550	715	1100	618.2	330–1200
Venlafaxine	18	48	62	86	465	766	276.3	39–1480
Others								
Quetiapine	9	62	74	140	220	324	158.4	61–380
Tramadol	21	22	47	120	260	1000	261.0	17–2000
Zolpidem	39	4	37	110	374	826	268.9	3–1500
Zoplicone	9	21	30	38	78	180	69.0	15–240

* The extreme value for free morphine were observed in accident cases. This may be due to a medical administration before the sampling. No medical information was available to confirm this hypothesis.

Table 4
Main toxicological results for the substances detected in the blood of 716 drivers suspected of driving under the influence of alcohol only (ALC) in 2018 and 2019 in Western Switzerland. Results reported as total number of positive (N) (≥ LLOQ), mean, median, range and percentiles (p5, p25, p75, p95) of the concentrations (g/kg for ethanol, µg/L for others).

Substance	N	p5	p25	Median	p75	p95	Mean	Range
Cannabinoids								
THC	36	1.1	1.6	3.2	4.4	8.8	4.7	1.0–52
THCCOOH	45	5.2	8.5	19.7	34.9	72.5	25.0	5.0–95
11-OH-THC	34	1.1	1.5	2.2	2.9	4.8	2.5	1.0 –6
CBD	18	1.8	3.5	6.9	21.5	69.7	20.2	1.1–119.0
Ethanol	596	0.48	1.02	1.54	1.91	2.53	1.51	0.14–3.80
Cocaine								
Cocaine	7	20	24	30	51	64	37.7	19–66
Benzoylecgonine	27	27	105	163	319	1148	321.7	23–1700
Methylecgonine	9	29	34	120	252	368	155.8	27–373
Ethylcocaine	1	44	44	44	44	44	44	44–44
Amphetamines								
Amphetamine	1	360	360	360	360	360	360	360–360
Methamphetamine	–							
MDMA	3	14	16	19	125	209	87.4	3–230
MDEA	–							
MDA	1	19	19	19	19	19	19	19–19
Opiates								
Free morphine	30	12	15	24	40	663	134.8	11–1868*
Free codeine	1	6	6	6	6	6	6	6–6
Methadone	2	110	166	236	306	362	235.8	96–376
EDDP	17	2	175	628	1006	2386	747.6	2–2623
Benzodiazepines								
Alprazolam	8	3	7	14	15	46	16.9	2–61
Bromazepam	8	17	27	64	152	443	138.6	17–553
Lorazepam	13	5	7	9	20	88	24.7	4–145
Midazolam	12	4	11	15	28	68	25.1	4–69
Nordiazepam	9	8	21	177	234	391	167.2	7–420
Oxazepam	14	6	13	63	172	584	171.6	3–702
Temazepam	9	19	43	109	126	153	89.7	15–161
Antidepressants								
Citalopram	11	35	49	99	143	206	106.6	32–234
Fluoxetine	3	76	110	154	382	565	277.1	67–610
Sertraline	4	12	28	43	91	184	75.6	8–208
Trazodone	3	349	369	394	429	457	401.0	344–464
Venlafaxine	5	72	103	211	266	407	217.5	64–443
Others								
Amlodipine	6	15	18	22	30	42	25.2	14–45
Diphenhydramine	4	6	14	28	43	54	28.9	4–57
Tilidine	6	1	1	2	3	5	2.2	1–5
Tramadol	5	31	76	127	228	498	203.0	18–566
Zolpidem	7	23	39	56	131	331	114.9	22–387

* The extreme value for free morphine were observed in accident cases. This may be due to a medical administration before the sampling. No medical information was available to confirm this hypothesis.

three most frequently detected drugs in accident cases were ethanol (N = 490, 47%), cannabinoids (N = 291, 28%), and benzodiazepines (N = 222, 22%). In contrast, in non-accident cases, mostly cannabinoids (N = 1531, 72%), cocaine (N = 546, 26%), and ethanol (N = 462, 22%) were found. As benzodiazepines were found only in 5% of non-accident cases (N = 114), this type of prescription drug clearly plays a central role in accident cases but is rarely detected during controls.

For the ALC cases, ethanol was the most frequently detected type of drug (84%, N = 602), followed by cannabinoids (13%, N = 91), benzodiazepines (9%, N = 65), antidepressants (6%, N = 42), opiates (5%, N = 35), cocaine (4%, N = 29), methadone (3%, N = 18), and amphetamines (1%, N = 6). Thus, prescription drugs such as benzodiazepines and antidepressants were frequently found in ALC cases, suggesting that those drugs are hard to detect although widely used. Finally, there was no observed variation between genders.

The positive results from the toxicological analysis of the blood samples, including mean, median, percentiles 5, 25, 75, and 95 as well as the concentration ranges for the most frequently detected substances are shown in Table 3 for DUID cases and Table 4 for ALC cases. For the main drugs found, their distribution is shown in Fig. 2. It's important to keep in mind that morphine and diazepam are commonly given by medical staff after accident but before sampling. Therefore, interpretation on prevalence and concentrations found for these substances must be done with some caution.

3.3. Cannabinoids

The technical limit for THC is 1.5 µg/L ± 30% (2.2 µg/L). In 78% (N = 1478) of the 1886 DUID cases where cannabinoid consumption was confirmed, THC blood concentration was above 1.5 µg/L. Moreover, for 67% (N = 1271) of the samples, the concentration was above 2.2 µg/L, indicating that those drivers could be prosecuted immediately. For the 91 ALC cases where cannabinoid consumption was confirmed, 32% of cases (N = 29) were above 1.5 µg/L and 26% (N = 24) above 2.2 µg/L.

In addition, DUID cases had higher concentrations compared to ALC cases (medians 4.6 µg/L and 3.2 µg/L respectively). This phenomenon may be linked to the circumstances, as ALC cases were mainly accident, which makes the evaluation of the consumption harder.

Furthermore, for DUID cases, the mean age of people with confirmed cannabinoid consumption was 30 ± 9 (S.D.) years, with a range between 15 and 72 years. For the ALC cases, the population was slightly older (*Kruskal-Wallis test value = 8.35, p-value = 0.0038*), with a mean of 35 ± 11 (S.D.) years (range 17–68 years). This

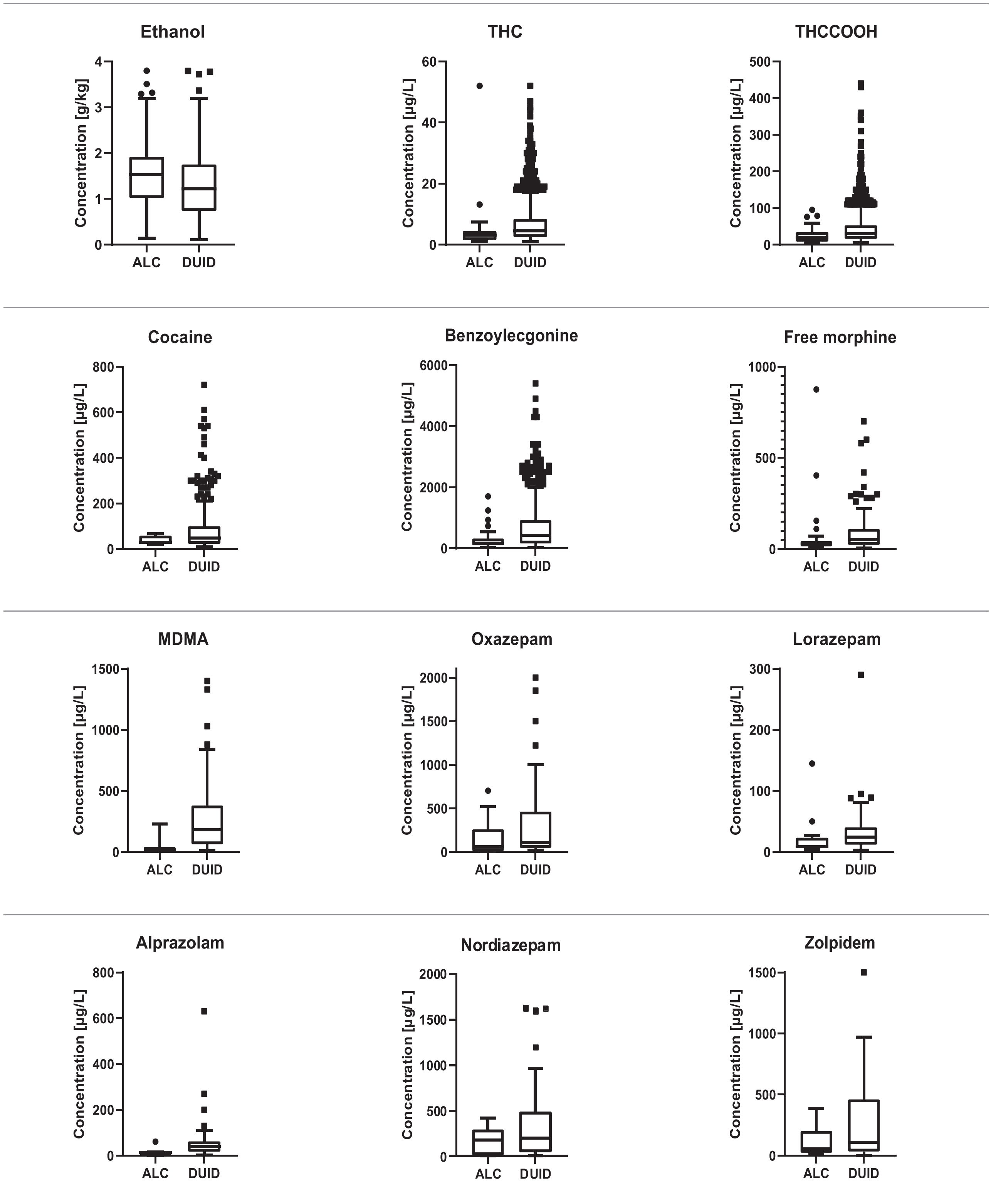

Fig. 2. Blood concentrations of the main drugs found in the 716 ALC cases and 3279 DUID cases. Extreme values for cocaine (N = 1 for DUID cases with concentration > 800 µg/L), for free morphine (N = 1 for DUID cases and N = 1 for ALC cases with concentration > 1000 µg/L), and for nordiazepam (N = 1 for DUID with concentration > 2000 µg/L) are not plotted for clarity. The whiskers and outliers are plotted using the Turkey method.

highlights the tendency not to suspect drug consumption in the older population.

Finally, in accordance with past studies [6–8], the THC blood concentrations for DUID cases were higher when cannabinoids were the only substances found (N = 960, mean = 7.2 µg/L) compared to cases involving poly-drug use (N = 620, mean = 5.8 µg/L, *Kruskal-Wallis test value* = *26.54, p-value* < 0.0001). For both, the high concentrations found among drivers speak in favor of a very recent use of cannabis and/or high doses taken.

3.4. Alcohol

Among all drinking drivers suspected of DUID, 12% (N = 86) had a BAC lower than the legal 0.5 g/kg threshold, and 15% (N = 105) between 0.5 g/kg and 0.8 g/kg, which is the limit for aggravated driving impairment. Finally, 72% (N = 502) were above 0.8 g/kg. Among those 502 drivers, 45% (N = 225) were above 1.6 g/kg, which is the concentration from which an evaluation of the aptitude to drive is mandatory. As previously observed for THC, alcohol concentrations were higher when alcohol was the only substance found (N = 205, mean = 1.38 ± 0.70) compared with cases with poly-drug use (N = 488, mean = 1.23 ± 0.66, *Kruskal-Wallis test value = 7.22, p-value = 0.0072*).

Among the ALC cases, 6% (N = 34) had a BAC lower than the 0.5 g/kg threshold, 9% (N = 52) between 0.5 g/kg and 0.8 g/kg, and 86% (N = 510) were above 0.8 g/kg, with 54% (N = 276) above 1.6 g/kg. Surprisingly, there was no difference between average concentrations in poly-drug use cases (N = 202, mean = 1.52 ± 0.62) versus only alcohol cases (N = 394, mean = 1.51 ± 0.65, *Kruskal-Wallis test value = 0.17, p-value = 0.6816*).

Finally, it is noteworthy that, for both DUID and ALC cases, a slight positive correlation between BAC and driver's age was observed (Spearman's rho = 0.12 and 0.15 respectively). Thus, the median BAC increased with age, and the highest median BAC was found among drivers of age 60–69 for DUID cases (1.6 g/kg), and 50–59 for the ALC cases (1.68 g/kg). This suggests a tolerance, within the population of older drivers, to the effects of alcohol that may come from regular consumption.

3.5. Cocaine

Cocaine and/or one of its metabolites (benzoylecgonine, ecgonine methylester, and cocaethylene) were found in 21% (N = 687) of DUID cases and only in 4% (N = 29) of ALC cases (*Pearson's X^2 test value = 07.00, p-value < 0.0001*). This emphasizes the police's efficiency in detecting this drug.

The technical limit for cocaine is 15 µg/L ± 30% (22 µg/L). Cocaine was detected in 13% (N = 412) of DUID cases. Its concentration was under the LLOQ (10 µg/L) in 9% (N = 38), under the 15 µg/L threshold in 9% (N = 37), and between 15 µg/L and 22 µg/L in 11% (N = 46) of those 412 cases. Thus, 71% (N = 291) cases were above the 22 µg/L legal limit. For the ALC cases where cocaine was detected (2%, N = 15), its concentration was above the 22 µg/L legal limit in 40% (N = 6). In addition, the mean age of people in whose blood cocaine and/or one of its metabolites were detected was 34 ± 14 (S.D.) years (13–95) for DUID and 45 ± 17 (S.D.) years (16–97) for ALC cases.

3.6. Other prescription drugs with abuse potential

Prescription drugs were found in 19% (N = 607) of DUID and in 18% (N = 130) of ALC cases. As expected [19], the most frequently found prescription drugs were benzodiazepines. The drugs of this class most encountered in DUID cases were oxazepam (N = 64), lorazepam (N = 62), nordiazepam (N = 56), midazolam (N = 41), and alprazolam (N = 36). For ALC cases, the benzodiazepines most often identified were oxazepam (N = 14), lorazepam (N = 13), midazolam (N = 12), nordiazepam (N = 9), and temazepam (N = 9). For both DUID and ALC cases, most concentrations found were within the expected therapeutic range [20,21]. However, some higher concentrations pointed to a misuse of benzodiazepines, which is an increasingly common use of these psychoactive substances [7]. The finding of supratherapeutic concentrations should motivate the introduction of legal limits for benzodiazepines, based on an accepted therapeutic range. Finally, the mean age of benzodiazepine consumers was 44 ± 16 (S.D.) years (range 16–94) for DUID and 52 ± 16 (S.D.) years (range 18–79) for ALC cases.

Antidepressants were the second most detected prescription drugs (N = 165 and N = 42 for DUID and ALC respectively). For DUID cases, citalopram (N = 33), venlafaxine (N = 18), and trazodone (N = 11) were the mostly found. For ALC cases, it was citalopram (N = 11), venlafaxine (N = 5), and sertraline (N = 4).

3.7. Poly-drug consumption

Poly-drug use is of concern because the interactions between drugs are not well known and may induce a large impairment on driving performance and/or increase the severity of trauma. Poly-drug use concerned 40% (N = 1299) DUID and 32% (N = 230) ALC cases.

For both DUID and ALC cases, the most frequent interaction was ethanol – cannabinoids, found in respectively 443 and 88 cases. This combination is known to severely diminish the driving performance [22]. Additionally, for the DUID cases, the next mostly found combinations were cannabinoids – cocaine (N = 313), ethanol – cocaine (N = 256), and ethanol – benzodiazepines (N = 137). Contrastingly, ALC cases showed mostly ethanol – benzodiazepines (N = 51), ethanol – antidepressants (N = 36), and ethanol – opioids (N = 31). Consequently, the high prevalence of prescription drugs found in interaction with alcohol in the ALC cases highlights the difficulty encountered by the police to detect such combinations.

Finally, these combinations were not equally represented within the circumstances. Indeed, for the DUID cases, ethanol – benzodiazepines, ethanol – antidepressants, and benzodiazepines – antidepressants were more detected in the 1034 accident cases (9.1%, 4.8%, and 5.8% of accident cases respectively) than in the 2134 non-accident ones (1.8%, 0.7%, and 1.3% respectively). These combinations all include prescription drugs, which highlights the danger of the combination of prescription drugs and alcohol for road safety. Consequently, this should motivate better information towards patients, as well as a prevention strategy concerning this type of drugs.

4. Conclusion

For the first time in Western Switzerland, this study presents a broad view on the prevalence of drugs found in blood of drivers suspected of driving under the influence of drugs (DUID cases) as well as drivers suspected of driving under the influence of alcohol only (ALC cases). This gives information on consumption habits and on the efficiency of the legislation strategy to detect drugs and alcohol during a control or after an accident.

Results show that there is an increase of the toxicological requests concerning bicycles, which parallels the increase in the use of bicycles seen at a national level. Their prevalence is even higher in accident than in non-accident cases, suggesting that the augmentation of their use has not changed the control strategy yet. The lack of controls toward bicycle riders may result in an underestimation of drug prevalence for this type of vehicles.

Toxicological results of DUID cases show that cannabinoids (58%), ethanol (30%), cocaine (21%), and benzodiazepines (11%) are the drugs most often detected. Prescription drugs, in particular benzodiazepines and antidepressants, are more often detected compared with last Swiss study [8]. Interestingly, these drugs are frequently found in accident cases and less in non-accident ones.

In ALC cases, ethanol (84%), cannabinoids (13%), benzodiazepines (9%), antidepressants (6%), opiates (5%), cocaine (4%), methadone (3%), and amphetamines (1%) were found. Moreover, alcohol suspicion was more frequent in case of accident than in case of non-accident, even if the police intuition was not correlated with toxicological results. This phenomenon, which we called *the influence of accident context*, generates an underestimation of the prevalence of other substances in road accidents and may lead to an inaccurate interpretation of their cause. Thus, after accidents, a systematic toxicological analysis should be recommended.

Concerning other prescription drugs with abuse potential, they were found in 19% of DUID and in 18% of ALC cases. The prescription drugs most frequently found were benzodiazepines. For both DUID and ALC cases, most concentrations found were within the expected therapeutic range. However, some higher concentrations pointed to a misuse of benzodiazepines.

Finally, poly-drug use concerned 39% of all cases analyzed. The most common combination was ethanol – cannabinoids. Moreover, ethanol – benzodiazepines, ethanol – antidepressants, and benzodiazepines – antidepressants were widely found in accidents and rarely in non-accident cases. The presence of prescription drugs in all these combinations emphasizes the issue of those drugs on driving and should promote a broad strategy of risk prevention. Moreover, the observation of supratherapeutic use of prescription drugs could be the driving force behind the introduction of a legal limit for these substances. To confirm driving impairment and improve the current zero-tolerance law, one could either resort to a *per se* approach, with a threshold defined at the level of the maximum dose therapeutically prescribed for each drug; or to a technical limit approach with zero tolerance for a list of substances.

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CRediT authorship contribution statement

Jonathan Maurer: Conceptualization, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Emeline Vergalito:** Investigation, Writing – review & editing. **Anne-Flore Prior:** Investigation, Writing – review & editing. **Nicolas Donzé:** Conceptualization, Resources, Writing – review & editing. **Aurélien Thomas:** Conceptualization, Writing – review & editing. **Marc Augsburger:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing, Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.forsciint.2021.111081.

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