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The incidence of psychoactive substances and alcohol among impaired drivers in Denmark in 2015–2019.☆

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ABSTRACT

This study examines the presence of psychoactive drugs and alcohol in blood from apprehended drivers driving under the influence of drugs (DUID) and alcohol in Denmark in a five-year period from 2015 to 2019.

Data were analysed with respect to gender, age, substances with concentrations above the Danish legal limit, arresting time of day and repeat arrest. By request of the police, the blood samples were subjected to analysis for alcohol and/or tetrahydrocannabinol (THC) alone, for "other drugs" (covering all drugs including new psychoactive substances (NPS), except THC, listed in the Danish list of narcotic drugs) or for both THC and other drugs.

About the same number of alcohol traffic cases (37,960) and drug traffic cases (37,818) were submitted for analysis for the five-year period. The number of drug traffic cases per year increased from 5660 cases in 2015 to 9505 cases in 2019, while the number of alcohol traffic cases per year (average, 7600) was unchanged.

Ethanol (89.2%) was the overall most frequent single substance, followed by THC (68.2%). CNS stimulants (46.8%) were the second most prevalent group of non-alcoholic drugs. Cocaine (23.8%) and amphetamine (22.9%) were the most frequent CNS stimulants. The proportion of CNS-stimulant positive drivers more than doubled in ten years. Benzodiazepines/z-hypnotics (12.7%) were the third most prevalent drug group detected, with clonazepam (8%) as the most frequent drug. Opioids were above the legal limit in 9.8% of the cases. NPS was above the legal limit in 128 cases (0.6%). Poly-drug use occurred in 40% of the DUID cases in the requested groups: other drug or other drug/THC.

Young males dominated the DUID cases (median age 26). Drink-drivers (median age 39) were also mainly men, but the age distribution was equally spread over the age groups.

Re-arrest occurred more often in DUID drivers (18–29%) than in drinking drivers (6–12%). DUID was evenly spread over the week, while drink-driving was most frequent on weekends.

This study is an important supplement to the knowledge of drug use in Denmark. It was the well-known psychoactive substances that were detected. Only a few NPS occurred. However, the abuse pattern has changed, and CNS stimulants now account for a much higher proportion than earlier. Our results indicate a drug use problem among DUID drivers. This gives rise to concern because of a risk of traffic accidents. Treating the underlying abuse problem is therefore recommended, rather than focusing solely on prosecuting.

1. Introduction

The influence of alcohol on driving performance is well established, and the connection between an increasing risk of road traffic crashes (RTCs) and increasing blood alcohol concentration (BAC) has been demonstrated [1,2]. In recent years, several case-control

☆ Note: Data from the eastern part of Denmark in 2015–2016 has been described in ref. [14] and THC data from the middle part of Denmark in 2017–2018 have been described in ref. [19].

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studies have demonstrated an increased risk of RTCs for drivers under the influence of substances like tetrahydrocannabinol (THC), amphetamines, opioids and benzodiazepines [2–9]. These studies indicate a connection between driving under the influence of drugs (DUID) and being injured or killed in traffic. However, a drug-positive driver is not necessarily impaired or responsible for a RTC [2,3].

Several factors like inattention, fatigue, high speed, illness etc. have significance for RTC. High speed is considered a key factor in RTCs, as speed influences both the risk of RTCs and serious injuries [10]. Bogstrand et al. have demonstrated a connection between alcohol, drugs and high speed among impaired, fatally injured drivers [11]. High speed and not wearing a seat belt were more frequent among the fatally injured drivers impaired by alcohol and/or amphetamines [11]. Poor judgement and risk-taking caused by alcohol or drug intake are speculated to be the reason for this behaviour.

Drivers under the influence of illicit drugs are often younger men, and poly-drug use is frequent [2,12–14]. Being a young male is a risk factor influencing crash involvement [10], but when combined with drug use and less experience in driving, these drivers presents a risk in traffic. A Swedish study has shown that fatally injured drivers impaired from amphetamines often had multiple offences [15]. Furthermore, a single DUID arrest may often be a result of several DUID events [16]. Society could benefit greatly from early intervention in the treatment of these groups of drivers [15,16]. This is especially true because poly-drug use, which is common among drug users, carries a high risk of getting injured in traffic [2]. Thus, a focus on DUID is an important factor in reducing RTCs.

A DUID impairment-based law had existed in Denmark for several years before the introduction of a fixed concentration limits law, but only a few drivers were convicted due to a cumbersome and expensive judicial procedure. The fixed concentration limits law has eased the procedure, as the laboratory reports form the basis for the evaluation of driving performance. In Denmark, the fixed concentration limits are determined on the basis of the lower therapeutic limits for medicinal drugs and the approximate lower blood concentration limits for a pharmacological effects of the illicit drugs. The fixed concentration limits correspond thereby to the lower concentration thresholds associated with a pharmacological effect. All psychoactive drugs, including new psychoactive substances (NPS) in the Danish list of narcotic drugs, are included in the Danish traffic legislation [17]. However, a clinical examination for the impact of prescription drugs is still performed and evaluated by a physician. These examinations are rarely requested.

Since the introduction of the fixed concentration limits law in Denmark in 2007, a considerable increase has occurred in charged drugged drivers [14,18]. Furthermore, the number of national DUID-related RTCs has increased since 2007 [19]. This does not precisely mean that the abuse of drugs has increased among drivers or in the community in Denmark. Rather, this increase has brought a hidden problem to light. However, it could also reflect a change in the abuse profile, as the number of impaired drink-drivers decreased by about 40% from 2011 to 2016 in the eastern part of Denmark, while the number of impaired drugged drivers increased nearly 155% [14].

The forensic laboratories in Denmark perform broad analytical screening of psychoactive drugs and alcohol in blood from drivers using the highest standard of analytical equipment. This allows monitoring of NPS and abuse patterns among drivers, while also providing an important supplement to the knowledge of the drugs available on the illicit market.

We have monitored the drug use trend among drivers by studying the incidence of psychoactive drugs and alcohol in impaired drivers in Denmark over the five-year period from 2015 to 2019. A particular emphasis was placed on the prevalence of NPS, and the results were compared with similar studies in other countries. The aim of this study was to define specific groups of drug users for which preventive measures could be of great societal interest.

2. Materials and methods

2.1. Materials

This study included all drivers with drug concentrations in their blood above the Danish legal limits investigated at the three sections of forensic chemistry (Copenhagen, Aarhus and Odense) in Denmark. Blood samples from drivers suspected of impairment and drivers stopped at random to test for impairment (i.e. police operations against drunken and/or drugged drivers in the period from 01 to 01–2015 to 31–12–2019) were investigated as requested by the police. The drivers suspected of impairment were typically stopped because of their driving behaviour or a history of DUID.

A breath test for alcohol and a drug screening apparatus (Dräger 5000) was routinely used by the police for roadside drug screening of the drivers. The Dräger instrument tested oral fluid for five different drugs or drug classes. The cut offs of the Dräger instrument is indicated in parenthesis: THC (5 ng/ml), benzoylecgonine (cocaine) (20 ng/ml), amphetamines (50 ng/ml), opioids (20 ng/ml) and benzodiazepines (15 ng/ml). In case of a positive test, information about drug use or a suspicion of other drugs, a blood sample was sent for forensic analysis. Only the results of the blood sample analysis had legal implications.

2.2. Analytical packages

The police could choose between four different analytical packages when submitting blood samples for analysis, Table 1. The choice of the packages was based on the roadside test, suspicion of drugs, etc. In the case of a positive breath test for alcohol, a blood sample was submitted for alcohol analysis.

The blood samples could be analysed either for alcohol, THC alone, other drugs, or THC plus other drugs. The alcohol package could be combined with one of the drug packages. “Other drugs” than THC included all drugs classified as dangerous in traffic, which is almost all euphoriant drugs (including NPS) according to Danish legislation [17]. Tramadol was also included in the study, even though it is not included in the list. A cut-off of 0.1 mg/kg, corresponding to the lower therapeutic level, was set for tramadol. For some drugs, such as MDMA (methylenedioxymethamphetamine) and MDA (methylendioxyamphetamine) or diazepam and nordiazepam, both the main drug and its metabolite are included in the legislation. In these cases, only one drug above the legal limit was reported and thereby included in this study. The parent compound was given the highest priority. In case of a positive result for both amphetamine and methamphetamine above the legal limit, an evaluation was made whether both drugs should be included. If the amphetamine concentration amounted to about 10% of the methamphetamine concentration, amphetamine was considered a

Table 1
Number (N) of traffic cases received for analysis in Denmark in 2015–2019. Percentage (%) of cases with values exceeding the legal limits.

	Analytical packages				
	Alcohol N (%)	THC alone N (%)	Other drugs N (%)	THC and other drugs N (%)	Drug Total N (%)
2015	7889 (89)	2260 (77)	1090 (66)	2310 (79)	5660 (76)
2016	7514 (88)	2867 (80)	1466 (68)	2423 (78)	6756 (77)
2017	7281 (89)	2792 (82)	1754 (66)	2873 (81)	7419 (78)
2018	7671 (90)	3257 (82)	1957 (65)	3264 (80)	8478 (77)
2019	7605 (89)	3735 (80)	2119 (62)	3651 (79)	9505 (76)
Total	37,960 (89)	14,911 (80)	8386 (65)	14,521 (80)	37,818 (77)

Note: Percentage (%) of cases above the legal limit is calculated within the different analytical packages. Since THC is found in two different analytical packages, the total percentages of THC in the material will differ from the data presented in this table.

Table 2
Number and frequency of the findings exceeding the fixed concentration limits in 2015–2019 for the most frequently detected substances in Denmark. Gender and median age are included.

	Fixed conc. limits mg/kg	Positive cases N	Positive cases %	Male (%)	Median Age Female	Median Age Male
Ethanol	**0.50 g/kg**	**33,861**	**89.2**	**89.1**	**43**	**39**
THC	**0.0010**	**20,083**	**68.2**	**95.6**	**26**	**25**
CNS stimulants[a]		**10,722**	**46.8**	**94.2**	**30**	**29**
Cocaine	0.010	5448	23.8	96.1	27	27
Amphetamine	0.020	5398	22.9	92.2	31	31
MDMA	0.020	745	3.3	93.9	28	25
Methylphenidate	0.010	207	0.9	87.4	38	35
Methamphetamine	0.020	86	0.4	97.7	23	35
Benzodiazepines/z-hypnotica[b]		**2908**	**12.7**	**90.4**	**36**	**33**
Clonazepam	0.0050	1826	8.0	91.1	34	34
Alprazolam	0.0050	601	2.6	91.0	32	30
Diazepam	0.10	451	2.0	90.9	32	31
Nordazepam	0.10	144	0.6	86.8	31	37
Nitrazepam	0.020	133	0.6	94.0	40	40
Chlordiazepoxide	0.20	123	0.5	89.4	44	41
Bromazepam	0.050	114	0.5	79.8	48	42
Oxazepam	0.10	77	0.3	87.0	34	35
Zopiclone	0.010	76	0.3	78.7	48	35
Zolpidem	0.080	31	0.1	58.1	44	42
Opioids total		**2251**	**9.8**	**91.0**	**41**	**37**
Methadone	0.050	913	4.0	90.0	42	41
Heroin/morphine	0.010	741	3.2	91.3	41	40
Tramadol[c]	(0.10)[c]	364	1.6	91.8	32	26
Oxycodone	0.010	299	1.3	91.6	29	28
Fentanyl	0.00050	156	0.7	91.0	30	29
Buprenorphine	0.00050	103	0.4	89.2	40	38
GHB	**20**	**352**	**1.5**	**92.6**	**26**	**29**
NPS total[d]		**128**	**0.6**	**89.8**	**24**	**32**
Etizolam	0.002	40	0.2	90.0	24	27
Phenazepam	0.005	35	0.2	82.9	23	33
Flubromazolam	0.001	23	0.1	95.7	30	36
Delorazepam	0.020	10	< 0.1	100	–	36
Diclazepam	0.005[e]	6	< 0.1	100	–	34
Deschloroetizolam	0.002[e]	1	< 0.1	100	–	38
Pyrazolam	0.005[e]	1	< 0.1	100	–	38
Ethylcathinone	0.020[e]	1	< 0.1	100	–	48
4- Fluoramphetamine	0.020[e]	2	< 0.1	50	24	38
Fluormethamphetamine	0.020[e]	1	< 0.1	100	–	38
MPA[d]	0.020[e]	1	< 0.1	100	–	39
Alpha-PVP[d]	0.020	1	< 0.1	100	–	42
mCPP[d]	0.020	1	< 0.1	100	–	36
DPT[d]	0.010[e]	1	< 0.1	100	–	20
Other drugs total		**427**	**1.9**	**93.2**	**27**	**26**
Ketamine	0.010	403	1.8	93.0	26	26
Cathine	0.05	11	< 0.1	100	–	37
LSD	0.0005	6	< 0.1	100	–	30
Phenobarbital	10	6	< 0.1	83.3	45	34
Psilocin		1	< 0.1	100	–	21

[a]Excluding the NPS stimulants; [b]Excluding the NPS benzodiazepines; [c]Not included in the Danish list of narcotic drugs. A cutoff of 0.1 mg/kg was used for inclusion; [d]MPA: Methiopropamine; Alpha-PVP: alpha-pyrrolidinovalerophenone; mCPP: meta-chlorophenylpiperazine; DPT: Dipropyltryptamine; [e]Suggested limit.

metabolite, and only methamphetamine was reported/included in the study [20]. The legal limits for the detected drugs are shown in Table 2.

A drug detected below the legal limit is considered not detected according to the Danish legislation and the driver will not be convicted.

2.3. Methods

Positive screening hits were always confirmed in independent analytical runs. For psychoactive drugs, quantitative results were reported in mg/kg as they were based on weighed samples. For alcohol, quantitative results were reported as per mille (w/w). In Denmark, the analytical results for psychoactive drugs are subtracted by 33% safety margin (reporting of minimums values) to compensate for analytical uncertainty. For ethanol, 5% of the measured value (minimum of 0.1 mg/kg) was subtracted instead. These reduced results were rounded to two significant digits and compared with the legal limits [17]. The outcome of the analysis (above or below the legal limit) was clearly marked on the forensic statement sent to the police.

The blood samples were preserved with sodium fluoride and potassium oxalate or sodium citrate and analysed upon receipt. The blood samples were stored at least at − 20 °C. Samples for alcohol analysis were stored at 4 °C.

The blood samples underwent protein precipitation and/or solid phase extraction (SPE) prior to screening for all drugs (including NPS), either on a gas chromatograph equipped with a mass spectrometer (GC-MS), an ultra-performance liquid chromatography-time of flight (UHPLC-TOF) MS instrument or an ultra-performance liquid chromatography–tandem mass spectrometry (UHPLC-MS/MS) apparatus. Positive hits in screening libraries were confirmed and quantified using UHPLC-MS/MS, except for some of the THC analyses that were performed by GC-MS. Representative methods have previously been described [19,21–23]. External quality programmes (Arvecon (TDM, BTMF, DHF), LGC Standards (Toxicology Scheme QT, CAP (FTC, SCDD))) were followed covering most compounds. The laboratories are accredited according to ISO 17025 and most

methods used were validated according to ISO17025. Few drugs like some seldom NPS, were not validated/accredited. However, the identification of these drugs were done using certified reference material whenever available. These results were reported as not accredited.

Ethanol in whole blood was determined on an Agilent gas chromatography system equipped with a 6890 flame ionisation detector (GC-FID) and a G1888 head-space sampler [14]. An external quality programme was followed.

The percentages of re-arrest of offenders were calculated in the five-year study period only in the given police district, as it was not possible to perform a calculation across police districts. The percentages are therefore minimum numbers.

2.4. Data handling

All results were extracted from LIMS systems used in the three different departments. The data were organized and calculated by use of Excel. Graphics were made in Excel.

2.5. Ethical issues

As this was a retrospective study on data routinely collected by the laboratories and totally anonymous, the survey did not need to be reported to the National Committee on Health Research Ethics in Denmark.

Due to data being anonymised, the alcohol results could not be paired with the drug results. The alcohol-positive group and drug-positive group are therefore treated separately.

3. Results

3.1. Number of samples received

In the investigation period from 2015 to 2019, the number of alcohol traffic cases (37,960) and drug cases (37,818) submitted for analysis were almost the same (Table 1). The number of drug cases per year increased 68%, from 5660 cases in 2015 to 9505 cases in 2019, while the number of alcohol cases per year was unchanged (Table 1). Alcohol was above the legal limits in 33,784 cases. The frequency of positive cases was higher for alcohol (89%) above the legal limit than for drug cases (77%), which amounted to 29,120 cases above the fixed concentration limit. The frequency of positive alcohol and drug cases was rather stable throughout the five-year period (Table 1). Samples submitted for alcohol analysis dominated in both 2015 and 2016. In the following years, this request pattern changed, and the number of drug cases increased beyond the number of alcohol cases.

3.2. Frequency of detected drugs

Table 2 presents the frequency of drugs with concentrations above the legal limits. Ethanol (89.2%) was the overall most frequent single substance detected above the legal limit, followed by THC (68.2%). CNS stimulants (46.8%) were the second most prevalent group of non-alcoholic drugs. Cocaine (23.8%) and amphetamine (22.9%) dominated in this group. Benzodiazepines/z-hypnotica (12.7%) were the third most prevalent drug group detected. Clonazepam (8%) was particularly frequent in this group, followed by alprazolam (2.6%) and diazepam (2%). Opioids were above the legal limit in 9.8% of the analysed cases. Methadone (4%), heroin/morphine (3.2%), tramadol (1.6%) and oxycodone (1.3%) were the most prevalent drugs among the opioids. The prevalence of GHB was 1.5%. Relatively few cases were positive for NPS (0.6%). Etizolam (0.2%), phenazepam (0.2%) and flubromazolam (0.1%) were the most prevalent NPS (Table 2).

More than one drug was reported above the fixed concentration limit in 6745 cases. This corresponds to detection of multiple drugs in 40% of all cases in the two groups: other drugs and THC plus other drugs. The combination of two drug was most common (69%) followed by three (21%) drugs per case. Two cases contained eight different drugs. This was the maximum number of drugs seen per case. THC was often detected with cocaine or amphetamine. MDMA was most often detected with THC or amphetamine than with cocaine while morphine was more frequently seen with cocaine than with amphetamine. Clonazepam was frequently seen with either THC, amphetamine or cocaine.

3.3. Gender and age

Men dominated all groups, especially the THC (95.6%) and CNS stimulant groups (94.2%) (Table 2). However, women accounted for a relatively larger share of positive z-hypnotics (zopiclone: 21.3% and zolpidem: 41.9%). Drivers with values above the legal limit for THC, CNS-stimulants, GHB and NPS were about 10–20 years younger than drivers having values above the legal limit for ethanol, opioids, several of the benzodiazepines and the z-hypnotics (Table 2). The age distribution differed between alcohol-positive cases and drug-positive cases (Fig. 1). The frequency of non-alcoholic drug cases peaked at age 22 (median age 26), while the age group for alcohol-positive cases peaked at both ages 22 and 49 (median age 39). The figure clearly shows that the drug-positive cases are centred especially in the younger group aged 18–30, while alcohol-positive cases are equally spread over the age groups.

THC, cocaine, amphetamine and clonazepam were the most prevalent drugs detected above the fixed concentration limits in all years (Table 3). The frequency of THC, cocaine and amphetamine was almost unchanged throughout the study period. The proportion of the opioids heroin/morphine and methadone decreased from around 5% in 2015 to 2–3% in 2019 (Table 3).

3.4. Other issues

Between 18% and 29% of the DRUID drivers were re-arrested more than one time in the study period. This is about three times more often than drivers driving under the influence of alcohol (6–12%).

Alcohol cases with concentrations above the legal limit were most frequently seized on weekends, especially in the nights/early mornings between Friday and Saturday and between Saturday and Sunday (Fig. 2). Traffic cases with non-alcoholic drugs were more evenly distributed throughout the week, but the number increased in the nights/early mornings from Thursday to Sunday.

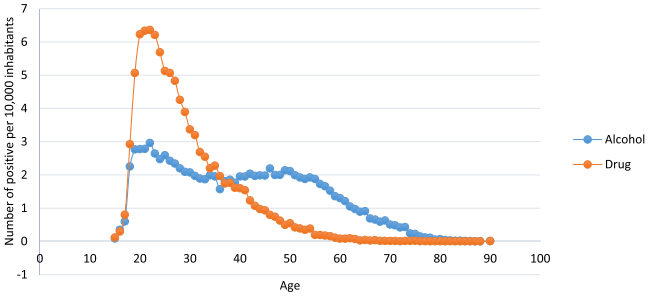

Fig. 1. Age distribution of drivers with values exceeding the legal limits per 10,000 inhabitants.

Table 3
Frequency (%) of the ten drugs most frequently detected above fixed concentration limits per year in Denmark.

Drug	2015	2016	2017	2018	2019
Tetrahydrocannabinol (THC)	65	68	69	70	68
Cocaine	19	23	26	26	24
Amphetamine	23	24	23	23	22
Clonazepam	8.9	9.0	8.8	7.1	6.8
Alprazolam	1.6	2.3	1.9	3.0	3.7
Methadone	4.7	5.1	4.0	3.6	3.2
MDMA	3.5	3.9	3.3	2.8	3.0
Heroin/morphine	5.1	3.7	3.0	2.7	2.5
GHB	2.3	1.4	1.6	1.1	1.5
Diazepam	2.6	2.1	2.2	1.9	1.4
Drug Total N	5660	6756	7419	8478	9505

4. Discussion

The present data give an impression of the drug use profile among drivers. The numbers can be used as an important indicator of general drug use, together with other indicators like street drug studies and fatal poisonings among drug addicts. This could be an aid in the early intervention to prevent impaired driving. Many of the drunken drivers do not belong to the drug user group, but a large proportion of those affected by illicit drugs (THC, cocaine, amphetamine etc.) do belong [14,15]. This provides an impression of what substances are present in streets, cafes and bars and thereby at the user level. Before the introduction of the fixed concentration law in 2007, non-alcoholic drug traffic cases only amounted to 200–250 cases yearly. This number showed a considerable increase and continues to increase. For the last three year, more traffic drug samples than traffic alcohol sample were received for analysis. This, together with the increase in criminal charges regarding RTCs related to DUID, could indicate a change in drug use, especially among youngsters, as the age profile peaks at 22 years. However, the police have been aware of drug testing as an effective and useful tool in traffic cases, and this may have led to the observed increase in cases.

Alcohol and THC were the overall most prevalent substances detected above the legal limits. Stimulants (cocaine and amphetamine) were in third place, followed by benzodiazepines and then opioids. This is partly in agreement with earlier findings in Denmark [18]. In 2008, THC (35%) was the most frequently found drug above the legal limit in the eastern part of Denmark, followed by clonazepam (13%), amphetamine (11%), heroin/morphine (9%) and cocaine (7%) [18]. The prevalence of CNS stimulants has clearly increased, especially for cocaine, compared to 2008 [18]. Our study showed a quite similar prevalence of cocaine and amphetamine. However, we cannot exclude the possibility that the prevalence of cocaine could have been significantly higher, as many blood samples were positive for the cocaine metabolite, benzoylegonine, while cocaine was below the legal limit. This was partly because of the time delay between arresting and blood sampling, taking into account the half-life of only about one hour.

Drivers with values above the legal limit for CNS stimulants and THC were approximately 10–20 years younger than drivers with values above the legal limit for methadone, heroin/morphine and many benzodiazepines/z-drugs. The WHO pointed out that young males have a high risk of traffic crashes [10] and a North American study, found that the crash risk was related to young males rather than to the use of THC [24]. Inexperience in driving could add to this risk. Taken together, young males driving under the influence represent a significant focus area.

The personality of the drivers and a desire for sensations has a bearing on risky behaviour in traffic [25]. Jamt et al. found a high degree of sensation seeking among CNS-stimulant impaired drivers, while sensation seeking was found only to a lesser extent in drivers impaired by THC and benzodiazepines [25]. In addition, amphetamine was the most prevalent non-alcoholic illicit drug among fatally injured drivers in Northern Europe [13]. In our study, CNS stimulants were the second most frequently positive non-alcoholic drugs.

Compared to the findings in fatally poisoned drug addicts in Denmark in 2017, where methadone was the most frequent single substance, opioids play a minor role among drivers [26]. This is in agreement with findings in a Norwegian study [27]. In the Danish study [26], methadone was more frequent among older drug users above 45 years of age, and the median age among the fatally poisoned drug users was high: 41 years [26].

The frequent detection of cocaine and clonazepam corresponds well with findings among fatally poisoned drug users in Denmark [26]. A street drug study (excluding cannabis) performed in 2018 revealed a predominant occurrence of cocaine in all parts of Denmark (64–84%), while amphetamine was much less frequent (8–36%) [28]. Thus, all studies indicate that cocaine has become a major player in the illicit market in Denmark. Therefore, prioritisation of treatment offers for CNS-stimulant users is recommended.

The Nordic countries (Denmark, Finland, Norway and Sweden) are quite similar according to classes of drugs detected in arrested drivers. THC, CNS stimulants, benzodiazepines and opioids are the most prevalent drugs detected [29]; however, some differences exist. While amphetamine was one of the most frequent drugs in all Nordic countries, cocaine, which was the second most prevalent drug in our study, only occurred to a lesser extent in the other Nordic countries [29]. In that context, Denmark has more in common with

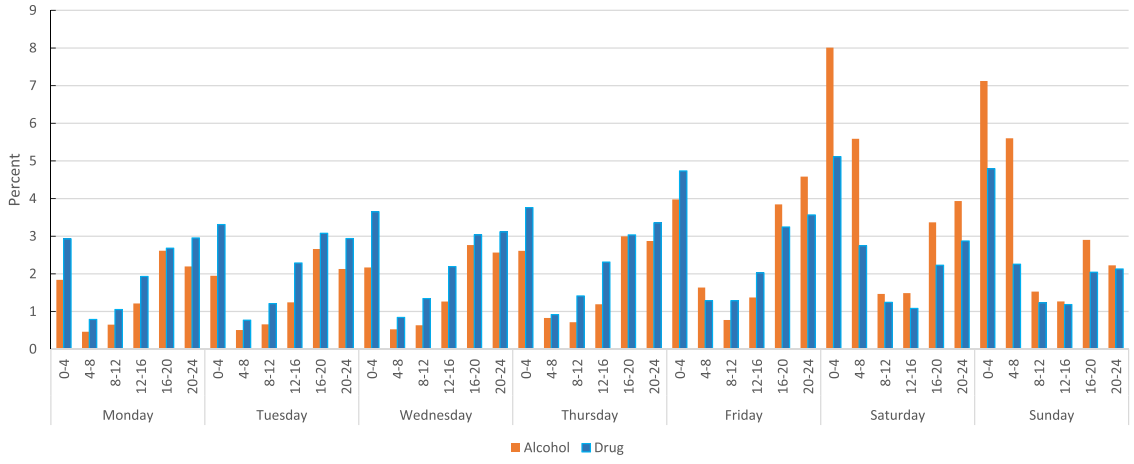

Fig. 2. Distribution of drivers with values exceeding the legal limits according to time of day and day of the week. Note: Time interval is divided into four hour intervals/segments and for clarity is presented from 0 to 4 am, 8–12 am, 16–20 am and 20–24 am.

southern European countries, such as Italy and Spain, where cocaine is one of the most prevalent drugs among drivers [30,31].

Methadone and heroin/morphine, the most frequent opioids in our study, were not detected in the other Nordic countries, except for heroin/morphine in Sweden [29]. Instead, buprenorphine occurred frequently in the other Nordic countries. THC, clonazepam and alprazolam were prevalent in all countries [29].

Tramadol is not a controlled substance in Denmark, but it is highly recommended for inclusion in the Danish list of narcotic drugs. Tramadol has a warning label in Denmark because it poses a risk in traffic, in line with drink-driving [32]. It was the third most frequent drug among the opioids in this study, and the numbers of tramadol offenders are comparable to those impaired by heroin/morphine. Tramadol appears frequently in both traffic and autopsy cases in Finland and Sweden and a higher prevalence in the future in Denmark cannot be excluded [29,33].

Our laboratories perform a broad analytical screening using UPLC-HR-TOFMS/UPLC-MSMS instruments for nearly all present NPS on the illicit market. Furthermore, we participate in international collaboration and exchange information such as libraries concerning NPS [34]. Despite using state of the art screening methods and updated libraries, only a few NPS were detected, and most were illicit benzodiazepines. NPS are a challenge for forensic laboratories, as about 50–100 new substances appear on the European illicit drug market every year [35]. Therefore, some new NPS entries on the market could have been missed in our analysis.

Another possibility is that NPS are simply not detected with the Dräger instrument used by the police. Blood samples from drivers having a negative oral fluid test, are not always sent to forensic analysis. The relatively high number of illicit benzodiazepines in the NPS group indicates this, because the Dräger equipment responds to this drug class. The attempt to avoid international law regulations is problematic for the authorities, since the NPS possesses effects comparable to the scheduled psychoactive substances and can therefore presumably impair driving [9,35]. Few reports have described NPS in impaired drivers. Among these is a Belgian study conducted in 2015 that found a prevalence of 7% NPS in blood, which is more than 10 times our findings [36]. This Belgian group found a wide variety of NPS that were also included in our analytical screening.

However, they included ketamine among the NPS. We did not include ketamine in the NPS group because, ketamine was on the illicit marked long before NPS was introduced. Nevertheless, the Belgian study detected 5–8 times more NPS, excluding ketamine, than we did [36]. The NPS were very frequent in a Hungarian study of suspected DUID drivers in 2014 and 2015, where 21–28% were positive for NPS CNS stimulants and 15–19% for synthetic cannabinoids (SC) in 2015 [37]. Other studies were limited to specific compounds, drug classes and case descriptions [9]. For example, investigators in Norway (2011–2012) and North America (2012–2013) limited their studies to the prevalence of SC in impaired drivers and found that 2.2% of the drivers in Norway and 3.6% in North America were positive for one or more SC [38,39].

Our data showed some regional differences (Table 4). Non-alcoholic drug-positive drivers were most prevalent in the Copenhagen area and southern Jutland (close to the German border). This could reflect that drug use is not just a metropolitan phenomenon but is also connected to areas close to borders or international airports, where drug trafficking occurs.

A higher prevalence of cocaine was observed in the eastern part of Denmark, while amphetamine was more prevalent in the western part, especially in Southern Jutland. These regional differences must be taken with some caution, however, as the available data depend on, among other things, the police effort and choice of analysis package.

Table 4
Prevalence of ethanol and the most frequent drug cases exceeding the legal limits per 10,000 inhabitants in the age group 17–80 years in the different police districts in Denmark in 2015–2019.

	Eastern part of Denmark Dept. Forensic Chem. Copenhagen University					Middle part of Denmark Dept. Forensic. Chem. Southern University		Western part of Denmark Dept. Forensic Chem. Aarhus University			
	Copen-hagen	Copen-hagen West area	Northern Zealand	Central- Western Zealand	Southern Zealand	Bornholm	Funen	Southern Jutland	South-East Jutland	Central-Western Jutland	Eastern Jutland	Northern Jutland
Inhabitants, N	615,844	311,028	444,390	349,741	292,706	31,264	381,874	336,597	361,373	442,749	459,122	405,025
Ethanol	57.5	54.2	53.4	83.9	97.3	97.2	86.3	85.9	92.8	98.8	60.9	85.5
Drug only	105.8	65.3	34.0	52.1	65.9	40.9	50.5	113.8	46.9	72	63.6	36.3
Tetrahydro-cannabinol (THC)	81.2	46.1	23.0	35.9	47.0	34.5	34.7	72.3	31.2	47.2	44.0	22.0
Cocaine	22.7	18.2	7.2	11.2	10.2	1.6	7.8	13.3	8.3	10.6	12.0	9.9
Amphetamine	6.2	5.7	5.9	8.6	13.5	6.1	12.6	36.3	9.1	18.3	13.7	8.1
Clonazepam	3.6	2.5	1.2	2.3	2.4	2.9	5.2	9.0	4.9	5.5	5.1	4.0
Methadone	2.5	1.7	0.8	1.5	2.2	0.6	3.1	3.2	2.2	3.3	1.4	0.7
MDMA	2.2	0.9	0.7	1.4	1.7	1.9	1.5	4.2	1.5	2.2	1.0	1.1
Heroin/morphine	2.5	1.0	0.5	0.8	1.0	0.3	3.3	2.9	1.6	1.9	1.5	0.9
Alprazolam	1.8	1.5	0.6	0.9	1.1	0.0	1.1	2.0	1.1	2.0	1.0	1.8
Diazepam	1.0	0.7	0.5	0.5	0.6	0.6	0.6	1.8	1.2	1.6	1.1	1.4
GHB	2.0	2.4	1.4	1.5	0.4	0.0	0.0	0.0	0.1	0.1	0.1	0.4

The more even distribution of non-alcoholic drug traffic cases during the week also substantiates an abuse among the drug-impaired drivers with a steady need for drugs, whereas the peak on weekends for alcohol-impaired drivers indicates that many drivers take the chance of driving home after a night out. Our findings are in agreement with a roadside study in North America and a study on fatally injured drivers in Canada. In these studies, alcohol-positive drivers were more frequently found on weekend nights, while drug-positive drivers were observed evenly over a week [40,41].

The high prevalence of alcohol and stimulants gives rise to concerns about the risk of high speed and therefore RTCs, which is not only a problem for the driver but also for road users and pedestrians. For society, it is a financial burden due to expenses for treatment, rehabilitation of the injured, etc.

Introduction of the fixed limit law has undoubtedly eased the police work in prosecuting DUID suspects, because obtaining the necessary evidence is less demanding than it had been earlier. In line with other countries (e.g. Sweden), our study shows that many of the drugged drivers were repeat offenders with several arrests [15]. Along with the frequent occurrence of illicit and licit psychoactive drugs and widespread poly-drug use, this indicates a drug use problem among several drivers. Like the study performed by Holmgren et al. [12] we recommend treating the underlying substance abuse to reduce DUID.

4.1. Limitations

The available data are biased because the submitted blood samples are a consequence of the police effort and choice of analytical package. The increase in drugged driving is presumable connected to the police efforts and a hidden problem has become visible.

If the Dräger equipment or the breath analyser was not used or equilibrated correctly by the police, false negative results could be obtained. Furthermore, if the police believe too much in the Dräger test, samples with false negative results i.e. NPS are not analyzed. Therefore, we cannot exclude that, some of the samples screened negative by the police could have been positive for drugs/alcohol not requested.

The samples were taken by the police according to driving style, suspicion of impairment and raid toward drunken and drugged driving and are therefore not randomly seized. Because of this, the results are not an expression of use of alcohol and drugs in the general traffic.

5. Conclusion

This study provides an important supplement to the knowledge of drug use in Denmark. THC is widely used among drivers, closely followed by CNS stimulants. The proportion of CNS-stimulant positive drivers has more than doubled in ten years, while opioids like heroin/morphine and methadone have decreased by a third to a low level. Young males dominated the cases, presumably because of risky behaviour and an inclination towards drug abuse. NPS drugs were seldom detected and seem not to be an issue in Denmark. However, the drug market is changing rapidly, and many new drugs emerge every year. Therefore, changes are likely in the future, and studies such as this one are important for monitoring drug abuse, trends and patterns.

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CRediT authorship contribution statement

Kirsten Wiese Simonsen: Conceptualization, Visualization, Writing – original draft, Supervision, Writing – review & editing, Project administration. **Jørgen Bo Hasselstrøm:** Data curation, Visualization, Writing – review & editing. **Simon Kjær Hermansen:** Data curation, Visualization, Writing – review & editing. **Brian Schou Rasmussen:** Data curation, Formal analysis, Visualization. **Mette Findal Andreasen:** Data curation, Visualization, Writing – review & editing. **Dorte Jensen Christoffersen:** Data curation, Visualization, Writing – review & editing. **Kristian Linnet:** Writing – review & editing.

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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