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# Drug consumption of suspected drug-influenced drivers in Hungary (2016–2018)

László Institóris[a], Előd Hidvégi[b], Katalin Kovács[a], Ákos Jámbor[a], Adrienn Dobos[b], Ferenc Rárosi[c], Gábor Süvegh[b], Tibor Varga[a], Éva M. Kereszty[a,*]

[a] Department of Forensic Medicine, Faculty of Medicine, University of Szeged, Szeged, Hungary
[b] Department of Forensic Toxicology, Hungarian Institute for Forensic Sciences, Budapest, Hungary
[c] Department of Medical Physics and Informatics, Faculty of Medicine, University of Szeged, Szeged, Hungary

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ABSTRACT

The hazard caused by driving under the influence of drugs (DUID) is determined by the time of consumption, dose and biological effects of a substance, as well as by synergistic drug interactions after multi-drug use. The aim of this work was to investigate the prevalence and pattern of psychoactive substance use of suspected DUID drivers and to present the advantages and disadvantages of the system currently used for determination of impairment in Hungary.

Blood and urine samples, collected between 2016 and 2018, were taken from 2369 drivers with a positivity rate of 95% for at least one substance. Classical illicit drugs were detected in 76–87%, prescription medications in 9–15%, stimulant New Psychoactive Substances (sNPS) in 3–8%, and synthetic cannabinoids (SCs) in 20–22% of the positive samples. The most frequent substances according to substance groups were: *classical illicit drugs*: cannabis (n = 1240), amphetamine and methamphetamine (AM/MA) (n = 753), MDMA (n = 196), and cocaine (n = 180), *medicines*: alprazolam (n = 188) and clonazepam (n = 83), *sNPS*: N-ethyl-hexedrone (n = 115), *SCs*: 5 F-MDMB-PINACA (n = 267), AMB-FUBINACA (n = 92) and ADB-FUBINACA (n = 90). The median age of classical illicit drugs users was 29 years, prescription medicine users were 33 years old, sNPS users were 28 years, and SC users were 26 years old. Compared to the previous two years, we found pronounced changes in the ratio of sNPS (14% decrease) and SC users (10% increase), and in the pattern of NPS consumption. The ratio of multi-drug use varied between 38% and 50%. 69% of drivers tested

*Abbreviations:* **4-CEC**, 4-chloro-ethcathinone; **4Cl-α-PVP**, 4-chloro-alpha-pyrrolidinopentiophenone; **4-Cl-PPP:**, 1-(4-chlorophenyl)−2-(1-pyrrolidinyl)−1-pentanone; **4-CMC**, 4-chloro-methcathinone; **4MENP**:, 4-methyl-N-ethyl-norpentedrone; **4F-MDMB-BINACA**, methyl-2-(1-(4-fluorobutyl)−1*H*-indazole-3-carboxamido)−3,3-dimethylbutanoate; **5F-AB-PINACA**, *N*-[1-amino-3-methyl-1-oxobutan-2-yl]−1-(5-fluoropentyl)indazole-3-carboxamide; **5F-ADB-PINACA**, *N*-(1-amino-3,3-dimethyl-1-oxobutan-2-yl)−1-(5-fluoropentyl)−1*H*-indazole-3-carboxamide.; **5F-AMB M**, N-[[1-(4-carboxybutyl)−1*H*-indazol-3-yl]carbonyl]-L-valine, 1-methyl ester; **5F-AMBICA**, N-[1-(aminocarbonyl)−2-methylpropyl]−1-(5-fluoropentyl)−1H-indole-3-carboxamide; **5F-AMB-PINACA**, methyl 2-{[1-(5-fluoropentyl)−1*H*-indazol-3-yl]formamido}−3-methyl-butanoate; **5F-CUMYL-PEGACLONE:**, 2,5-dihydro-2-(1-methyl-1-phenylethyl)−5-(5-fluoropentyl)−1*H*-pyrido[4,3-*b*]indol-1-one; **5F-MDMB-PICA:**, methyl 2-(1-(5-fluoropentyl)−1*H*-indole-3-carboxamido)−3-methylbutanoate; **5F-MDMB-PINACA:**, methyl 2-[1-(5-fluoropentyl)−1*H*-indazole-3-carboxamido]−3,3-dimethylbutanoate; **AB-CHMINACA:**, *N*-[1-amino-3-methyl-1-oxobutan-2-yl]−1-(cyclohexylmethyl)indazole-3-carboxamide; **AB-FUBINACA:**, *N*-[1-amino-3-methyl-1-oxobutan-2-yl]−1-[(4-fluorophenyl)methyl]indazole-3-carboxamide; **AB-PINACA:**, *N*-[1-(aminocarbonyl)−2-methylpropyl]−1-pentyl-1*H*-indazole-3-carboxamide; **ADB-CHMINACA,**, *N*-[1-amino-3,3-dimethyl-1-oxobutan-2-yl]−1-(cyclohexylmethyl)indazole-3-carboxamide; **ADB-FUBINACA:**, *N*-(1-amino-3,3-dimethyl-1-oxobutan-2-yl)−1-(4-fluorobenzyl)−1*H*-indazole-3-carboxamide; **AKB-48F:**, N-(adamantan-1-yl)−1-(5-fluoropentyl)−1*H*-indazole-3-carboxamide; **α-PVP:**, 1-phenyl-2-(1-pyrrolidinyl)−1-pentanone; **AMB-CHMICA:**, methyl 2-{[1-(cyclohexylmethyl)indole-3-carbonyl]amino}−3-methylbutanoate.; **AM/MA:**, amphetamine/methamphetamine; **AMB-FUBINACA:**, methyl-2-{[1-[(4-fluorophenyl)methyl]indazole-3-carbonyl]amino}−3-methylbutanoate; **BZE:**, benzoyl-ecgonine; **CUMYL-4CN-BINACA:**, 1-(4-cyanobutyl)-*N*-(2-phenylpropan-2-yl)−1*H*-indazole-3-carboxamide; **CUMYL-5 F-P7AICA:**, 1-(5-fluoropentyl)-N-(2-phenylpropan-2-yl)pyrrolo[2,3-*b*]pyridine-3-carboxamide; **CUMYL-CH-MEGACLONE:**, 2,5-dihydro-2-(1-methyl-1-phenylethyl)−5-(cyclohexylmethyl)−1*H*-pyrido[4,3-*b*]indol-1-one; **CUMYL-PEGACLONE:**, 2,5-dihydro-2-(1-methyl-1-phenylethyl)−5-pentyl-1*H*-pyrido[4,3-*b*]indol-1-one; **EPh:**, ethylphenidate; **EMB-FUBINACA:**, ethyl(1-(4-fluorobenzyl)−1*H*-indazole-3-carbonyl)-L-valinate; **JHW-122:**, (4-methyl-1-naphthyl)-(1-pentylindol-3-yl)methanone; **MAB-CHMICA:**, N-[1-(aminocarbonyl)−2,2-dimethylpropyl]−1-(cyclohexylmethyl)−1*H*-indole-3-carboxamide; **MAB-CHMINACA:**, *N*-[1-amino-3,3-dimethyl-1-oxobutan-2-yl]−1-(cyclohexylmethyl)indazole-3-carboxamide.; **MAM-2201:**, (1-(5-fluoropentyl)−1*H*-indol-3-yl)(4-methyl-1-naphthalenyl)methanone; **MDMA:**, 3,4-methylendioxy-methamphetamine; **MDMB-CHMICA:**, methyl −2-{[1-(cyclohexylmethyl)−1*H*-indol-3-yl]formamido}−3,3-dimethylbutanoate; **MDMB-FUBICA:**, methyl 2-({1-[(4-fluorophenyl)methyl]−1*H*-indol-3-yl}formamido)−3,3-dimethylbutanoate; **MDMB-FUBINACA:**, methyl 2-{[1-[(4-fluorophenyl)methyl]indazole-3-carbonyl]amino}−3,3-dimethylbutanoate.; **MMB-2201:**, methyl 2-(1-(5-fluoropentyl)−1*H*-indole-3-carboxamido)−3-methylbutanoate.; **NEH:**, N-ethyl-hexedrone; **THJ-2201:**, [1-(5-fluoropentyl)−1*H*-indazol-3-yl](1-naphthyl)methanone; **UR-144:**, (1-pentylindol-3-yl)-(2,2,3,3-tetramethylcyclopropyl)methanone; **AUC:**, area under curve; **C-I:**, confidence interval; **DFM:**, Department of Forensic Medicine; **DUID:**, driving under the influence of drugs; **HIFS:**, Hungarian Institute for Forensic Sciences; **ROC:**, receiver operating characteristics; **sNPS:**, stimulant New Psychoactive Substance(s); **SCs**, synthetic cannabinoids; **SFST:**, standardized field sobriety test

* Correspondence to: Department of Forensic Medicine, Faculty of Medicine, University of Szeged, Kossuth L. sgt. 38, Szeged H-6724, Hungary.
*E-mail address:* kereszty.eva.margit@med.u-szeged.hu (É.M. Kereszty).

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positive were deemed impaired. Impairment was determined according to impairment limits (80–82%), multi-drug use (12–13%), and the result of medical investigation when a single active substance with no set impairment limit was detected in the blood (6–8%). The results of medical investigations may be uncertain due to the long time delay between arrest and clinical examination and to the structure of medical investigations created for determination of alcoholic impairment. In conclusion, a revision of the current medical investigation protocol is warranted to standardize clinical symptom scores that better correlate with driving impairment.



## 1. Introduction

Driving under the influence of drugs (DUID) is an important risk factor of traffic accidents. The illicit, licit drug and New Psychoactive Substance (NPS) consumption of drivers can be investigated in the general driver population [1,2], in suspected DUID drivers [3–5], or in drivers involved in traffic accidents with personnel injury or fatal outcome [3,6–8].

The investigation of drug consumption in the driving population is an important component of traffic accident prevention. In the latest Hungarian investigation from 2014 to 15, illicit, licit drug and NPS consumption was evaluated among suspected DUID drivers with a positivity rate of 78–80%. The most frequently abused illicit drugs were cannabis and amphetamine, licit drugs were alprazolam and clonazepam, and NPS were pentedrone, α-PVP, AB-CHMINACA and MDMB-CHMICA. Drivers with a positive test were found impaired in 45–50% of the cases [9]. The international comparison of the positivity rate of impairment among suspected DUID drivers is challenging Positivity for drugs does not necessarily mean that the driver is clinically classified impaired, it depends on the wording of the law of a given country. Impairment can be determined by the “impairment approach" (a driver is deemed impaired if he/she produces the clinical symptoms of impairment), or by ”per se” limit (if the blood concentration of a substance exceeds a limit concentration). “Impairment” or “influenced” by law may be based on a “two-tier” system, which is the combination of the former two [10].

In Hungary, where the current study was performed, impairment is practically defined in a “two-tier” system. For the majority of classical illicit drugs and medicines there are impairment limits defined by the protocols of the evaluating experts, who take into consideration the internationally used limits. For substances with no impairment limit, the driver is deemed impaired if one active substance is detected in the blood and the person shows clinical symptoms of impairment. Multi-drug users (when at least two active substances are detected in the blood) are classified impaired regardless of the clinical signs and drug concentration [9].

Determination of impairment for NPSs is poorly defined, given the lack of relevant epidemiological studies. Thus, when one NPS is detected in the blood impairment is deemed according to the results of the medical investigation performed at the time of blood sampling. The long delay between arresting and medical investigation questions the validity of the diagnosis.

This study is the follow-up of our earlier investigation (2014–15) of illicit, licit drug and NPS consumption of suspected DUID drivers in Hungary [9]. Its aim was (1) to reveal the changes in the pattern and frequency of drug consumption compared with 2014–15, and (2) to present some factors which lead to uncertain clinical diagnoses when sampling the suspected DUID drivers.

## 2. Materials and methods

### 2.1. Drivers and sampling

The subjects of this study were drivers stopped by the police due to aberrant or reckless driving, during traffic control, or when drug consumption was suspected (N = 2369 cases). Those who were involved in traffic accidents were not evaluated in this study. When both drug use and alcohol consumption was suspected, breath alcohol was tested by the police (N = 1234 cases) and its quantitative result was included in this study. A medical doctor took blood samples in 10 ml DB Vacutainer® plastic tubes containing silica clot activator, and/or urine samples in leak proof urine collection cup, and registered the clinical symptoms according to the standard protocol in Hungary. This protocol involved the examination of the following: 1/ eye symptoms (the width of the pupils, pupil light reaction, nystagmus), 2/ coordination and speech (Romberg probe, finger to nose probe, speech disturbance), 3/ cognitive functions (data communication, remembering/memory, orientation), and 4/ behavior (irritability, restlessness, aggressive behavior, dullness). The result of clinical investigation was classified positive if (i) alteration was registered in at least two of the above categories, (ii) all symptoms were positive within groups 1/ or 3/, or (iii) two symptoms were positive in group 2/. Personal information, time of sampling, and the results of the urine quick test (if performed) were also registered. Blood and urine samples were stored at 4–8 °C until analysis.

### 2.2. Analysis

The samples were analyzed by the Department of Forensic Toxicology of the Hungarian Institute for Forensic Sciences (HIFS), as described [9]. In January of 2016, 228 substances (including metabolites) were analyzed in total and this number increased to 283 by July of 2018. For qualitative analysis of NPSs purified standards were provided by the Drug Investigation Department of the Hungarian Institute for Forensic Sciences (HIFS), standards for quantitative analysis were purchased from Cayman Chemical, USA. All other standards were purchased LGC Standards GmbH (Germany) or Lipomed AG (Switzerland).

### 2.3. Data processing and determination of impairment

Analytical data, age and gender of the drivers, the time of arresting and sampling, and the results of medical investigation, were processed at the Department of Forensic Medicine, University of Szeged (DFM). All data were assigned to the drivers by a code for unanimous analysis, we had no access to medical databases (including medication prescriptions).

Legal impairment was adjudicated by the court based on police reports, results of medical investigation, analytical results, and the opinion of forensic experts.

Medical impairment was determined by a forensic expert according to the following criteria in order:

1/ *impairment limit*: presence of at least one active substance in the blood with a concentration over the impairment limit (breath alcohol over 0.25 mg/l);.

2/ *multi-drug use*: presence of two or more active substances in the blood samples irrespective of their impairment limit;.

3/ *clinical symptoms*: presence of one active substance in the blood with no impairment limit and the clinical signs of impairment.

The definition "active substances" also involves active metabolites. The carboxylic acid metabolites of SCs were regarded inactive [11].

The impairment limits for blood are presented in Table 1. In this study AM and MA were combined, while AM can be a metabolite of MA. MDA was regarded the metabolite of MDMA, as it was seized only once in the period.

### 2.4. Statistical analysis

Categorical data were expressed as number cases (frequencies) and proportions (percentages), continuous data were expressed as mean ± SD and median and quartiles if appropriate. Proportion of categorical data with respect to years was compared with chi-square test for independence, median age of men and women were compared by Mann-Whitney U-test. Median ages and age distribution of positive cases according to years and substance groups were compared with Kruskal-Wallis test, post-hoc comparisons were conducted with the Dunn-Bonferroni approach.

A p-value $p < 0.05$ was regarded as statistically significant. Statistical software IBM SPSS 26 was used for analysis.

The study was approved by the Human Investigation Review Board of the University of Szeged (permission number: 30/2020-SZTE).

## 3. Results

### 3.1. The investigated population

In 2016–18 altogether 2369 suspected DUID drivers were sampled of which 2256 (95%) were tested positive (drug-positive cases) for at least one substance, including breath alcohol. 97% of drug positive cases were men. Substances with n > 5 prevalence, their cut off, concentration interval and median are presented in Table 2. No significant difference was found in the gender and age distribution between the sample and drug-positive cases ($p > 0.05$ in all comparison). The age distribution of drug-positive cases was: 1% was < 18 years, 32% was 18–24 years, 42% was 25–34 years, 24% was 35–49 years, and 1% was ≥ 50 years. 95% of them were man with median age (quartiles 1st,3rd) of 28 (23,34) years, and 5% were woman with median age of 31 (24,38) years ($p = 0.017$).

### 3.2. Distribution of drug-positive drivers according to substance groups and the prevalence of the most frequently used substances

The median age of classical illicit drug users was 29 years, of medicine users was 33 years, of sNPS users 28 years, and of SCs users 26 years. The most frequent age group of classical illicit drug users was 25–34 years during the whole investigation period. Medicine users were most frequently in the 35–49 years age group in 2016 and in the 25–34 years group in 2017–18. The most common age for sNPS users was 18–24 years in 2016 and 2018, and 35–49 years in 2017; for SC users 18–24 years in 2016 and 25–34 years in 2017–18 (Fig. 1).

The percentage of those who used classical illicit drugs varied between 76% and 82%. Within this group cannabis was the most prevalent (n = 1240, 55%) followed by AM/MA (n = 743, 33%), MDMA (n = 196, 9%).and cocaine (n = 180, 8%). The ratio of drivers who took medicines increased from 8 (2016) to 13–14%. The most frequently used medications were alprazolam (n = 188, 8%) and clonazepam (n = 83, 4%). The percentage of sNPS users increased from 3% to 8%, and in this group N-ethyl-hexedrone (n = 115, 5%) was the most prevalent. SCs were detected in 21– 22% of the drug-positive samples. During the three years 5 F-MDMB-PINACA (n = 267, 12%) was the most frequent followed by AMB-FUBINACA (n = 91, 4%), ADB-FUBINACA (n = 90, 4%), 5 F-MDMB-PICA (n = 34, 1.5%), MDMB-CHMICA (n = 20, < 1%), and AB-FUBINACA (n = 15, < 1%) (Table 3). AB-FUBINACA carboxylic acid was detected in 246 samples of which only the metabolite was present in 200 cases. The prevalence of the substances among impaired drivers was ranked the same.

**Table 1**
Impairment limits for blood.

| Substances | Impairment limits (ng/ml) |
|---|---|
| Amphetamine | 50 |
| Methamphetamine | 50 |
| Methylendioxyamphetamine | 50 |
| Methylendioxymethamphetamine | 50 |
| Cocaine | 50 |
| Benzoyl-ecgonine | 50 |
| THC | 2 |
| Morphine | 20 |
| GHB | 30 (μg/ml) |
| Breath alcohol | 0.25 (mg/l) |
| Medicines | The upper limit of the therapeutic range[a] |

[a] Considering the possibility of prescription based use of medications the upper limit of the therapeutic range of medicinal drugs was chosen as impairment limit.

Although the percentage of alcohol positive cases (altogether 143 drivers out of the 1234 tested for breath alcohol) slightly decreased by years from 14% to 10% but the difference was not statistically significant ($p > 0.05$). A similar tendency was observed among drivers who were classified impaired. Alcohol was present alone in 7 cases and in combination with drugs in 136 cases.

### 3.3. Multi-drug use

The ratio of multi-drug users was 38% in 2016, 50% in 2017, and 49% in 2018. The most frequent combinations were *cannabis* with classical stimulants (AM/MA, MDMA, cocaine) and SCs, *classical stimulants* with each other, benzodiazepines and SCs, *synthetic cannabinoids* with each other, benzodiazepines, and classical stimulants (Suppl. Table 1A). The most frequent benzodiazepines, alprazolam and clonazepam, were found alone only in 16% and 20% of cases, respectively. Compared to 2016, the ratio of drivers who used two substances in 2017–18 significantly decreased ($p < 0.05$) while the ratio of those who used 3 or 4 substances increased ($p < 0.05$) (Suppl. Table 1B). In the samples of 244 drivers two or more SCs and/or their metabolites were detected (24 drivers in 2016, 88 in 2017, and 132 in 2018). The most prevalent combinations of two or three active substances in the blood samples are presented in Suppl. Table 1C.

### 3.4. Impairment

Out of the 2260 drug-positive drivers 1553 (69%) were classified impaired. In the majority of cases impairment was determined according to impairment limit (80 – 82%) or multi-drug use (12 – 13%), and only in 6 – 8% according to clinical symptoms (Table 4).

### 3.5. Deficiencies in driver testing

Deficiencies in driver testing are presented in Table 5. The percentage of incomplete documentation related to all tested drivers significantly decreased over the years ($p < 0.05$ in all comparison). In 2018 significant decrease was observed in the percentage of cases when only urine samples were taken ($p < 0.05$ versus the former years). The duration between arresting and sampling (154 – 170 min) did not change significantly by year ($p > 0.05$). For impaired drivers a significant increase was found in 2018 in the number of cases when the time of sampling was not registered versus the former years ($p < 0.05$).

**Table 2**
Cut offs, concentration intervals and median for frequent (n > 5) substances.

| Substances | Blood (ng/ml) | | | | Urine (ng/ml) | | | |
|---|---|---|---|---|---|---|---|---|
| | Cut off | Conc. interval | Median | N | Cut off | Conc. interval | Median | N |
| Amphetamine | 5 | 5.00–1954 | 79.9 | 663 | 100 | 100–80000 | 2710 | 67 |
| MA | 5 | 5.10–1724 | 175 | 157 | 100 | 100–5330 | 470 | 10 |
| MDA | 5 | 5.00–199 | 21.7 | 86 | 100 | 270–17820 | 620 | 16 |
| MDMA | 5 | 9.25–980 | 104 | 171 | 100 | 140–37540 | 3540 | 21 |
| THC | 1 | 1.10–53.8 | 5.50 | 670 | | | | |
| THC-OH | 1 | 1.00–24.2 | 2.65 | 692 | | | | |
| THC-COOH | 1 | 1.11–269 | 27.4 | 1134 | 15 | 17.0–2000 | 326 | 106 |
| Cocaine | 5 | 6.00–163 | 6.50 | 7 | 20 | 20.5–20480 | 22.2 | 6 |
| BZE | 10 | 13.0–13900 | 149 | 147 | 30 | 35.7–44090 | 460 | 33 |
| Morphine | 5 | 7.00–35.0 | 18.5 | 4 | 500 | 501–2000 | 1951 | 3 |
| Codeine | 5 | 6.00–10.0 | 8.50 | 4 | 300 | 1421–1751 | | 2 |
| GHB (μg/ml) | 5 | 28.0–412 | 65.0 | 16 | 10 | 500 | | 1 |
| Methadone | 20 | 20.0–344 | 114 | 8 | 100 | 300 | | 1 |
| Ketamine | 20 | 22.6–962 | 139 | 11 | 100 | 3000–15000 | | 2 |
| Norketamine | 20 | 20.0–830 | 197 | 20 | | 3000–15000 | | 2 |
| Dehydronorketamine | 20 | 94.8–980 | 159 | 7 | | 3000–15000 | | 2 |
| Tramadol | 30 | 38.5–997 | 91.7 | 4 | 200 | 8.04 | | 1 |
| Alprazolam | 5 | 5.00–939 | 30.2 | 177 | 20 | 22.5–201 | 9.56 | 11 |
| HO-alprazolam | 5 | 5.00–27.0 | 7.50 | 17 | 20 | 21.0–23.0 | | 2 |
| Clonazepam | 5 | 5.00–595 | 50.0 | 65 | 20 | 35.6 | | 1 |
| 7-amino-clonazepam | 5 | 5.00–1409 | 33.0 | 73 | 20 | 32.0–151 | 113 | 5 |
| Diazepam | 5 | 10.0–619 | 40.1 | 10 | 20 | | | 0 |
| Nordazepam | 5 | 8.00–751 | 61.0 | 11 | 20 | | | 0 |
| Carbamazepine | 5 | 37.8–18830 | 2760 | 10 | 100 | 108 | | 1 |
| Midazolam | 5 | 5.00–414 | 81 | 7 | 20 | | | 0 |
| HO-midazolam | 5 | 5.00–23.0 | 15.5 | 5 | 20 | | | 0 |
| Mirtazapine | 5 | 5.00–72.0 | 17.0 | 6 | 20 | | | 0 |
| Citalopram | 5 | 7.00–112 | 22.3 | 14 | 20 | 384 | | 1 |
| NEH | 5 | 10.2–640 | 30.7 | 78 | 100 | 130–15000 | | 37 |
| 4-methyl-N-ethyl-norpentedron | 5 | 17.5–23.9 | 20.7 | 5 | | qualitative | | 3 |
| AB-CHMINACA | 0.1 | 0.38–2.38 | 1.03 | 5 | | | | 0 |
| AB-CHMINACA **M** | 0.1 | 0.15–8.86 | 1.92 | 6 | | | | 0 |
| AB-FUBINACA | 0.1 | 0.29–1.58 | 0.58 | 9 | 0.1 | 0.18–2.31 | 0.68 | 5 |
| AB-FUBINACA **M** | 0.1 | 0.10–286 | 1.12 | 226 | 1.0 | 1.19–11.8 | 10.0 | 34 |
| ADB-FUBINACA | 0.1 | 0.11–23.4 | 3.78 | 65 | 0.1 | 0.17–0.70 | 0.28 | 3 |
| ADB-FUBINACA **M** | 0.1 | 0.14–14.9 | 0.96 | 27 | | qualitative | | 8 |
| AMB-FUBINACA | 0.1 | 0.10–10.1 | 0.11 | 59 | | qualitative | | 24 |
| CUMYL-4CN-BINACA | | qualitative | | 12 | | qualitative | | 1 |
| CUMYL-PEGACLONE | 0.1 | 0.25–4.01 | 0.34 | 7 | | | | 0 |
| 5 F-CUMYL-PEGACLONE | | qualitative | | 8 | | qualitative | | 1 |
| 5 F-ADB-PINACA | | qualitative | | 3 | 0.1 | 0.12–2.46 | 0.37 | 6 |
| 5 F-AMB **M** | 0.1 | 0.20–19.0 | 1.06 | 11 | 1.0 | 3.40–4.80 | 4.10 | 3 |
| 5 F-MDMB-PINACA | 0.1 | 0.10–20.0 | 0.40 | 222 | 0.1 | 0.10–1.34 | 0.23 | 18 |
| 5 F-MDMB-PINACA **M** | 0.1 | 0.13–18.9 | 4.45 | 136 | | qualitative | | 17 |
| 5 F-MDMB-PICA | 0.1 | 0.10–11.8 | 1.36 | 25 | | qualitative | | 3 |
| 5 F-MDMB-PICA **M** | 0.1 | 0.13–14.1 | 0.87 | 19 | | qualitative | | 1 |
| MDMB-CHMICA | 0.1 | 0.12–10.0 | 0.50 | 19 | | qualitative | | 1 |
| MDMB-FUBICA | | qualitative | | 5 | | | | 0 |
| MAB-CHMINACA | 0.1 | 0.38–5.77 | 4.06 | 6 | 0.1 | 0.10 | | 1 |
| Breath alcohol (mg/l) | 0.1 | 0.1 – 1.69 | 0.53 | 128 | | | | |

**N**: the number of drivers tested positive for a given substance; **Conc. interval**: concentration interval; **M**: carboxylic acid metabolite; Median is calculated only for ≥ 3 numeric values.

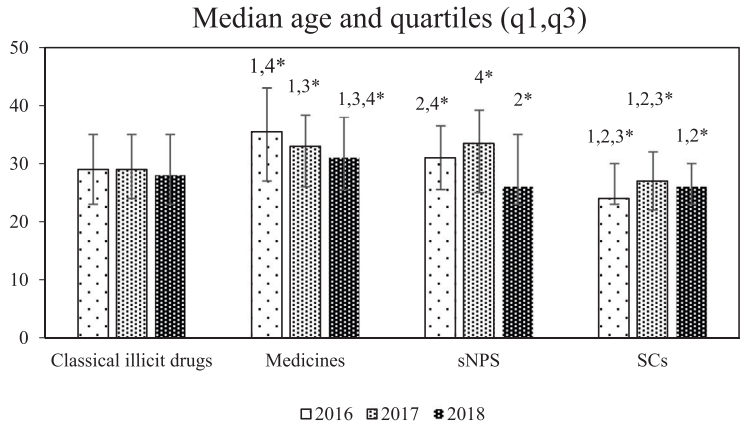
## 4. Discussion

The findings of our studies reveal important changes in the drug consumption of suspected DUID drivers between 2014 and 2018 [9].

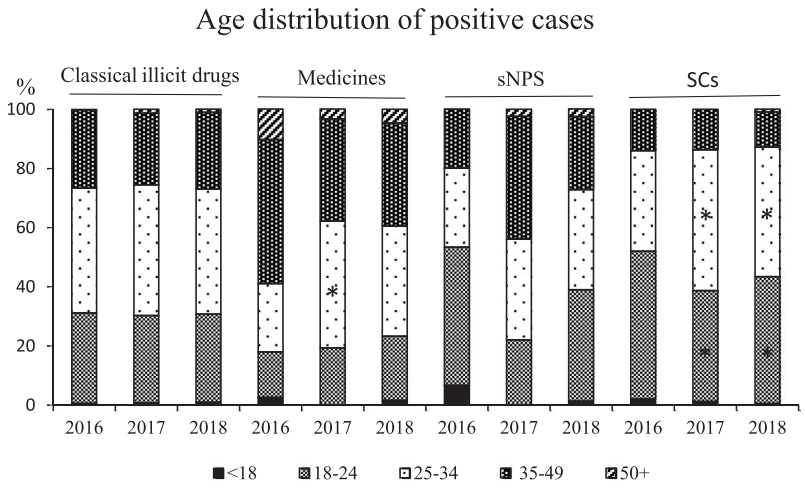
Compared to 2014 – 2015 the frequency of drug-positive and impaired drivers increased by 11–16% and by 17–24%, respectively. While the age range of classical illicit drug and SC users was the same in both periods, medicine use shifted towards the lower, and SC use towards the higher age groups in 2016–18. The percentage of classical illicit drug and SC users increased while the frequency of sNPS and medications decreased. The two most prevalent benzodiazepines, alprazolam and clonazepam were present alone in only 15–20% of the positive samples, which suggests that the majority of drivers abused these substances.

In 2014–15, the "top five" substances were cannabis, AM/MA, pentedrone, alprazolam and cocaine, in 2016–18 the rank was the same but pentedrone was replaced by 5 F-MDMB-PINACA. The pattern of sNPS and SC consumption also changed: the previously most frequent sNPS (pentedrone, 4-CMC, α-PVP) were replaced by other substances (mainly by N-ethyl-hexedrone), the former most prevalent SCs (AB-CHMINACA and MDMB-CHMICA) were surpassed by AMB-FUBINACA, ADB-FUBINACA and 5 F-MDMB-PINACA. These findings are concordant with the seizure data for the entire country (Suppl. Table 2).

Drug consumption of suspected DUID drivers was also investigated in other European countries. Between 1990 and 2015 in Norway 63% of the sampled drivers were tested positive for drugs, of which benzodiazepines (57%), stimulants (51%), and cannabis (34%) were the most prevalent. The ratio of ≥ 40 age group continuously increased by years for all substance groups especially for opiates and benzodiazepines [3]. In Denmark (2015–2019) 76% of suspected DUID drivers were positive for drugs over the legal limits. In both investigation period (2015–2016 and 2017–2019) the percentage of the most prevalent substances was nearly the same. The most




*p<0.05 by Kruskal-Wallis test (post hoc: Dunn-Bonferroni test); *1*- vs. classical illicit drugs, *2*- vs. medicines, *3* – vs. sNPS, *4* – vs. SCs in the corresponding year. No significant difference was found when the average ages were compared within the substance groups according to years.




*p<0.05 by chi-square test vs. 2016; sNPS: stimulant New Psychoactive Substances; **SCs**: synthetic cannabinoids;

**Fig. 1.** Median ages and age distribution of positive cases according to years and substance groups. *p < 0.05 by Kruskal-Wallis test (post hoc: Dunn-Bonferroni test); *1*- vs. classical illicit drugs, *2*- vs. medicines, *3* – vs. sNPS, *4* – vs. SCs in the corresponding year. No significant difference was found when the average ages were compared within the substance groups according to years. *p < 0.05 by chi-square test vs. 2016; sNPS: stimulant New Psychoactive Substances; **SCs**: synthetic cannabinoids.

frequent illicit drugs were cannabis (68%), cocaine (28%), and amphetamine (16%). The frequency of drug positive cases peaked in the 18–22 age group [4,5]. In Hungary the most frequent substances were cannabis (55%), AM/MA (33%), and 5 F-MDMB-PINACA (12%), the most prevalent age group was 25–34 years. Due to several factors, such as drug consumption habits of the population, availability, price, etc., the prevalence of illicit and licit drug consumption of suspected DUID drivers show differences internationally. In Hungary, for example, the prevalence of NPS use of drivers tested positive was about 23% while in Denmark it was very low [5].

The percentage of breath alcohol positive cases among the tested drivers (continuously) decreased by year. Although, we have no information about the drug consumption of drivers tested only for blood and/or urine alcohol. Clinical symptoms of drugs (especially in low concentration) can be masked in combination with alcohol, therefore those who produced symptoms characteristic for alcohol might have been tested for alcohol only.

The rate of multi-drug use slightly varied between 41% and 52% (2014–2018) except 2016 then it was only 38%. It may be explained by, at least in part, that while AMB-FUBINACA was detected from Jan. of 2016, AB-FUBINACA carboxylic acid (the common metabolite of AB-FUBINACA, AMB-FUBINACA and EMB-FUBINACA) was not analyzed until December of 2016. The number of seizures for the entire country in 2016–18 for AMB-FUBINACA was 936, 576, 327, respectively but for EMB-FUBINACA and for AB-FUBINACA it was below 40 cases/year (Suppl. Table 2). It means that the majority of AB-FUBINACA carboxylic acid positive drivers very likely used AMB-FUBINACA. According to the results of Morrow et al. [12] AMB-FUBINACA was present in the blood of postmortem cases only in 26% of carboxyl metabolite positive cases. The half-life of SCs seems to be short as we found it for 5 F-MDMB-PINACA (2.65 h) and 5 F-MDMB-PICA (2.70 h) when time-serial blood samples of intoxicated drug users were analyzed [13]. The average time-period between arresting and sampling in 2016 was 170 min, during which the mother compounds could completely metabolize. Thus, the estimated loss of AMB-FUBINACA positive drivers could be about 70% which also explains the lower percentage of multi-drug use in 2016. It would be important to shorten the sampling interval after the police control to prevent the data loss. By the Hungarian law the blood and urine samples are accepted for proof at the court, so alternative sampling has no place at this time.

We found an increase in the number of “multi-SC users” (220 drivers in 2017–18 versus the 24 drivers in 2016). According to seizure data of 2016–18, 15–37% of seized plant materials contained

**Table 3**
Frequency of substances according to substance groups among drug-positive and impaired drivers.

| **Classical illicit drugs** | **2016** | | | | | **2017** | | | | | **2018** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$N_1$= 370 (76.3%)[a]** | | | | **$N_2$= 244 (79.0%)[b]** | **$N_1$= 665 (82.4%)[a]** | | | | **$N_2$= 470 (87.2%)[b]** | **$N_1$= 742 (76.7%)[a]** | | | | **$N_2$= 579 (83.8%)[b]** |
| | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** |
| Cannabis | 144 | 106 | 250 | *67.6* | 152 | 221 | 251 | 472 | *71.0* | 325 | 252 | 266 | 518 | *69.8* | 397 |
| AM/MA | 67 | 95 | 162 | *43.8* | 123 | 78 | 181 | 259 | *38.9* | 200 | 101 | 231 | 332 *+ | *44.7* | 289+ |
| MDMA | 1 | 29 | 30 | *8.11* | 25 | 9 | 63 | 72 * | *10.8* | 59 * | 7 | 87 | 94+ | *12.7* | 79+ |
| Cocaine | 14 | 24 | 38 | *10.3* | 29 | 17 | 45 | 62 | *9.32* | 46 | 17 | 63 | 80 | *10.8* | 64 |
| Morphine | | 1 | 1 | *0.27* | | | 4 | 4 | *0.60* | 2 | | 2 | 2 | *0.27* | 2 |
| Codeine | 1 | 0 | 1 | *0.27* | 1 | | 2 | 2 | *0.30* | 1 | | 3 | 3 | *0.40* | 3 |
| Methadone | | | | | | | 5 | 5 | *0.75* | 4 | | 4 | 4 | *0.54* | 4 |
| GHB | 2 | 2 | 4 | *1.08* | 4 | 3 | 5 | 8 | *1.20* | 7 | | 5 | 5 | *0.67* | 5 |
| LSD | | | | | | | | | | | | 3 | 3 | *0.40* | 2 |
| Fentanyl | | | | | | | | | | | 2 | 1 | 3 | *0.40* | 2 |
| Ketamine | 2 | 5 | 7 | *1.89* | 4 | 2 | 4 | 6 | *0.90* | 4 | 2 | 6 | 8 | *1.09* | 6 |
| **Medicines** | **2016** | | | | | **2017** | | | | | **2018** | | | | |
| | **$N_1$= 41 (8.45%)[a]** | | | | **$N_1$= 29 (9.39%)[b]** | **$N_1$= 119 (14.7%)[a]** | | | | **$N_2$= 112 (20.8%)[b]** | **$N_1$= 130 (13.4%)[a]** | | | | **$N_2$= 110 (15.9%)[b]** |
| | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** |
| Tramadol | | 2 | 2 | *0.49* | 1 | | | | | | | 3 | 3 | *2.31* | 2 |
| Alprazolam | 6 | 19 | 25 | *43.9* | 18 | 10 | 73 | 83 | *69.7* | 69 | 14 | 66 | 80 | *61.5* | 69 |
| Clonazepam | 4 | 9 | 13 | *31.7* | 9 | 1 | 31 | 32 | *26.9* | 32 | 6 | 32 | 38 | *29.2* | 34 |
| Diazepam | 1 | 1 | 2 | *0.49* | 1 | | 2 | 2 | *1.68* | 2 | | 9 | 9 | *6.92* | 9 |
| Midazolam | | | | | | | 3 | 3 | *2.52* | 3 | | 4 | 4 | *3.08* | 4 |
| Carbamazepine | 2 | 1 | 3 | *4.88* | 2 | | 4 | 4 | *3.36* | 4 | | 3 | 3 | *2.31* | 3 |
| Other benzos | 3 | 4 | 7 | *12.2* | 5 | | 1 | 1 | *0.84* | | 1 | 7 | 8 | *6.15* | 8 |
| Mitrazapine | | | | | | | 5 | 5 | *4.20* | 5 | 1 | | 1 | *0.77* | |
| Tiapride | | 1 | 1 | *0.49* | 1 | | 1 | 1 | *0.84* | 1 | | 2 | 2 | *1.54* | 2 |
| Citalopram | | 1 | 1 | *0.49* | 1 | 2 | 5 | 7 * | *5.88* | 4 | | 7 | 7 | *5.38* | 7 |
| Buprenorphine | | 1 | 1 | *0.49* | 1 | | | | | | | 1 | 1 | *0.77* | 1 |
| Z-drugs | | | | | | | 1 | 1 | *0.84* | 1 | | 1 | 1 | *0.77* | 1 |
| **sNPS** | **2016** | | | | | **2017** | | | | | **2018** | | | | |
| | **$N_1$= 15 (3.09%)[a]** | | | | **$N_2$= 6 (1.24%)[b]** | **$N_1$= 41 (5.08%)[a]** | | | | **$N_2$= 14 (2.60%)[b]** | **$N_1$= 79 (8.16%)[a]** | | | | **$N_2$= 51 (7.38%)[b]** |
| | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** |
| Mephedrone | 1 | | 1 | *8.33* | 1 | | | | | | | 3 | 3 * | *3.80* | 3 * |
| Pentedrone | | 2 | 2 | *16.7* | 1 | | | | | | | | | | |
| 4MENP | 1 | 1 | 2 | *16.7* | 1 | 1 | 4 | 5 | *12.2* | 2 | | 1 | 1+ | *1.27* | 1 *+ |
| NEH | 4 | 2 | 6 | *50.0* | 2 | 16 | 19 | 35 * | *85.4* | 11 * | 27 | 47 | 74 * | *92.4* | 50 * |
| NEP | | | | | | | 1 | 1 | *2.44* | 1 | | 2 | 2 | *2.53* | 1 * |
| α-PVP | | 1 | 1 | | 1 | | | | | | | | | | |
| 4-CMC | 1 | 2 | 3 | *25.0* | | | | | | | | | | | |
| 4Cl-α-PVP | | | | | | | 2 | 2 | *4.88* | | | | | | |
| EPh | | | | | | | 1 | 1 | *2.44* | | | | | | |
| 4-CEC | | | | | | 1 | | 1 | *2.44* | | 2 | | 2 | *2.53* | 1 |
| **Synthetic cannabinoids** | **2016** | | | | | **2017** | | | | | **2018** | | | | |
| | **$N_1$= 99 (20.4%)[a]** | | | | **$N_2$= 58 (18.8%)[b]** | **$N_1$= 168 (20.8%)[a]** | | | | **$N_2$= 93 (17.3%)[b]** | **$N_1$= 213 (22.0%)[a]** | | | | **$N_2$= 111 (16.1%)[b]** |
| | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** |
| 4 F-MDMB-BINACA | | | | | | | | | | | 1 | 3 | 4 | *1.88* | 3 |
| 5 F-ADB-PINACA | | | | | | | 4 | 4 | *2.38* | 1 | | 7 | 7+ | *3.29* | 3 |
| 5 F-AMB M | | | | | | | 4 | 4 | *2.38* | 3 | | 10 | 10+ | *4.69* | 6+ |
| 5 F-AMBICA | 0 | 1 | 1 | *1.01* | 1 | | | | | | | | | | |
| 5 F-AMB-PINACA | | | | | | | 1 | 1 | *0.60* | 1 | | | | | |
| 5 F-CUMIL-PEGACLONE | | | | | | | 1 | 1 | *0.60* | | 2 | 6 | 8+ | *3.76* | 7 |
| 5 F-MDMB-PICA | | | | | | 3 | 11 | 14 | *8.33* | 11 | 3 | 17 | 20+ | *9.39* | 13+ |
| 5 F-MDMB-PINACA | 4 | 7 | 11 | *11.1* | 5 | 8 | 60 | 68 * | *40.5* | 42 * | 32 | 156 | 188 *+ | *88.3* | 99 *+ |
| AB-CHMINACA | | 2 | 2 | *2.02* | 2 | | 3 | 3 | *1.79* | 3 | | | | | |
| AB-FUBINACA | | 1 | 1 | *3.03* | | | 9 | 9 * | *5.36* | 5 | | 5 | 5 * | *2.35* | 4 |
| AB-FUBINACA M | 1 | 1 | 2 | *2.02* | 2 | 6 | 118 | 124 * | *73.8* | 73 * | 3 | 117 | 120 *+ | *56.3* | 66 * |
| AB-PINACA | 0 | 1 | 1 | *1.01* | 1 | | | | | | | | | | |
| ADB-CHMINACA | 1 | | 1 | *1.01* | 1 | | 1 | 1 | *0.60* | 1 | | | | | |
| ADB-FUBINACA | 19 | 26 | 45 | *44.4* | 33 | 1 | 36 | 37 | *22.0* | 20 * | | 8 | 8 *+ | *3.76* | 7 *+ |
| AKB-48 F | | | | | | | | | | | | 2 | 2 | *0.94* | 2 |
| AMB-CHMICA | | | | | | | 2 | 2 | *1.19* | 2 | | | | | |
| AMB-FUBINACA | 12 | 20 | 32 | *32.3* | 19 | 3 | 30 | 33 * | *20.2* | 19 | 1 | 25 | 26 | *12.2* | 17 *+ |
| CUMYL-4CN-BINACA | 5 | 6 | 11 | *11.0* | 5 | | 2 | 2 * | *1.19* | 2 | | | | | |
| CUMYL-5 F-P7AICA | | | | | | | | | | | | 1 | 1 | *0.47* | 1 |

(*continued on next page*)

**Table 3** (*continued*)

| **Classical illicit drugs** | **2016** | | | | | **2017** | | | | | **2018** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$N_1$= 370 (76.3%)[a]** | | | | **$N_2$= 244 (79.0%)[b]** | **$N_1$= 665 (82.4%)[a]** | | | | **$N_2$= 470 (87.2%)[b]** | **$N_1$= 742 (76.7%)[a]** | | | | **$N_2$= 579 (83.8%)[b]** |
| | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** |
| **Synthetic cannabinoids** | **2016** | | | | | **2017** | | | | | **2018** | | | | |
| | **$N_1$= 99 (20.4%)[a]** | | | | **$N_2$= 58 (18.8%)[b]** | **$N_1$= 168 (20.8%)[a]** | | | | **$N_2$= 93 (17.3%)[b]** | **$N_1$= 213 (22.0%)[a]** | | | | **$N_2$= 111 (16.1%)[b]** |
| | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** | **A** | **C** | **Sum** | **%** | **IMP** |
| CUMYL-CH-MEGACLONE | | | | | | | | | | | | 1 | 1 | *0.47* | 1 |
| CUMYL-PEGACLONE | | | | | | 2 | 5 | 7 | *4.17* | 4 | | | | | |
| EMB-FUBINACA | | | | | | | 2 | 2 | *1.19* | | | | | | |
| JHW-122 M | 0 | 1 | 1 | *1.01* | 1 | | | | | | | | | | |
| MAB-CHMICA M | | | | | | | 1 | 1 | *0.60* | 1 | | | | | |
| MAB-CHMINACA | 3 | 2 | 5 | *5.05* | 2 | | | | | | | | | | |
| MAB-CHMINACA M | | | | | | | 2 | 2 | *1.19* | 2 | | | | | |
| MAM-2201 | 0 | 1 | 1 | *1.01* | 1 | | | | | | | | | | |
| MDMB-CHMICA | 2 | 12 | 14 | *14.1* | 12 | | 6 | 6 | *3.57* | 6 | | | | | |
| MDMB-FUBICA | | | | | | | 5 | 5 | *2.98* | 4 | | | | | |
| MDMB-FUBINACA | | | | | | | 1 | 1 | *0.60* | 1 | | 1 | 1 | *0.47* | 1 |
| MMB-2201 | 0 | 1 | 1 | *1.01* | 1 | | | | | | | | | | |
| THJ-2201 | 0 | 2 | 2 | *2.02* | 2 | | | | | | | | | | |
| UR-144 | | | | | | | 2 | 2 | *1.19* | 1 | | | | | |

Other benzos: (Lorazepam, Olanzapine, Clobazam, Nitrazepam, Medazepam, Cinolazepam); Z-drugs: Zopiclone, Zolpidem.
sNPS: stimulant designer drugs; 4MENP: 4-methyl-N-ethyl-norpentedrone; NEP: N-ethylpentylone; NEH: N-ethyl-hexedrone; EPh: ethylphenidate.
N1: number of drivers tested positive to any drug of the corresponding group, (%)a percentage of the same drivers related to all positive cases; N2: number of impaired drivers tested positive to any drug in the corresponding substance group; (%)b: percentage of the same drivers related to all impaired cases in the corresponding year; %: percentage of drivers tested positive for a given substance related to N1; IMP: number of impaired drivers tested positive for a given substance; A: alone, C: in combination; Bold: the frequency is higher than 10% at least in one year;
*p < 0.05 versus 2016, +p < 0.05 versus 2017 by chi-square test;
**AB-FUBINACA M**: the common metabolite of AB-FUBINACA, AMB-FUBINACA and EMB-FUBINACA; **5 F-AMB M**: the common metabolite of 5 F-AMB-PINACA and 5 F-AB-PINACA;

two to six SC components (Tamás Csesztregi, personal communication, Drug Investigation Department, HIFS) which explains the relatively high rate of multi-SC use. The multi-drug use of suspected DUID drivers does not represent the general drug user population: the ratio of multi-drug users among suspected DUID drivers in 2018 (49%) was higher than of suspected drug users in the first half of 2018 (34%) [14].

In most cases, impairment was deemed according to per se limit or multi-drug use and in 6–8% according to clinical symptoms. The later procedure was used when only one active substance was detected in the blood, which has no impairment limit. The advantage of using per se limits or multi-drug use for impairment determination is that medical impairment does not have to prove which makes the enforcement process easier and faster. Compared with Denmark the ratio of NPS use is much higher in Hungary, in these cases medical investigation is necessary for determination of legal impairment. The clinical diagnosis of impairment is challenging, because the investigation requirements and checklist was elaborated for the effects of alcohol consumption. There is no specific symptom of drug-impairment in general or the consumed substance, so the non-specific symptoms need a complex evaluation by the examining clinician. Additional tests could give more confidential diagnosis.

The predictability of clinical investigations to indicate driving impairment of cannabis users was studied by comparing simulated driving performance, Standardized Field Sobriety Tests (SFSTs), and medical investigation results. The authors concluded that SFTSs and medical investigations often lack sensitivity to cannabis induced driving impairment [15–17]. Gustavsen et al. [18] compared the blood concentration of AM/MA and clinical symptoms of suspected impaired drivers. They grouped the positive cases according to blood concentration categories and found that the percentage of drivers classified impaired increased by the elevating blood concentration of AM/MA in the 40–540 ng/ml range but then reached a plateau. Driving impairment was proven in driving simulator study and cognitive function tests at 92 ng/ml MA and at 203 ng/ml MDMA blood concentrations [19], but they are much higher than the per se limits which used in the European countries [20].

Beside the structure of the currently used medical investigation in Hungary there are other factors leading to uncertain clinical diagnosis. (1) The degree of tolerance for a given substance depends mainly on the history of drug use: regular users need a higher dose to reach the desired effect, which is accompanied by a higher blood concentration. (2) The time-period between drug use and medical investigation, as well as the dose consumed is unknown. The pattern and severity of clinical symptoms of stimulant users depend on the phase of the effect: the most characteristic symptoms appear during the “bingeing” phase while in the “come down” phase resembles symptoms of fatigue [21]. According to Arkell et al. [15] THC blood

**Table 4**
The number of impaired drivers and assessment of impairment.

| | **2016** | | **2017** | | **2018** | | **Total** | |
|---|---|---|---|---|---|---|---|---|
| **Number of drivers tested positive** | **N = 485** | | **N = 803** | | **N = 968** | | **N = 2256** | |
| **Number of drivers classified impaired** | **N = 311 (64.1%)[a]** | | **N = 543 (67.6%)[a]** | | **N = 699 (72.2%)[a]** | | **N = 1553 (68.8%)[a]** | |
| **Assessment of impairment** | **Abs** | *%* | **Abs** | *%* | **Abs** | *%* | **Abs** | *%* |
| According to per se limit | **250** | *80.4* | **443** | *81.6* | **563** | *80.5* | **1256** | *80.9* |
| Multi-drug use | **36** | *11.6* | **68** | *12.5* | **89** | *12.7* | **193** | *12.4* |
| Presence of an active substance without per se limit, with clinical symptoms | **25** | *8.04* | **32** | *5.89* | **47** | *6.72* | **104** | *6.70* |

p > 0.05 in all comparison by chi-square test; a percentage of drivers tested positive.

**Table 5**
Deficits in driver testing.

| **All drivers tested** | **2016** N = 534 | **2017** N = 832 | **2018** N = 1003 |
|---|---|---|---|
| Medical examination was not performed or registered | 55 (10.3%) | 96 (11.5%) | 103 (10.3%) |
| Only urine sample was taken | 68 (12.7%) | 107 (12.9%) | 59 (5.88%)[a,b] |
| Time of sampling was not registered | 81 (15.2%) | 58 (6.97%)[a] | 74 (7.38%)[a] |
| **Incomplete documentation** | 204 (38.2%) | 261 (31.4%)[a] | 236 (23.5%)[a,b] |
| No breath alcohol test was performed or registered | 284 (53.2%) | 386 (46.4%)[a] | 469 (46.8%)[a] |
| Time delay of sampling (minutes) (mean ± SD) | 170 ± 125 | 170 ± 150 | 154 ± 103 |
| **Impaired cases** | **2016** N = 314 | **2017** N = 511 | **2018** N = 693 |
| Medical examination was not performed or registered | 21 (6.73%) | 37 (7.24%) | 66 (9.52%) |
| Time of sampling was not registered | 6 (1.92%) | 20 (3.91%) | 37 (5.34%)[a] |
| **Incomplete documentation** | 27 (8.60%) | 57 (11.2%) | 104 (15.0%)[a,b] |
| No breath alcohol test was performed or registered | 284 (90.4%) | 233 (45.6%)[a] | 384 (55.4%)[a,b] |

[a] $p < 0.05$ vs. 6016.
[b] $p < 0.05$ vs. 2017 by chi-square test; **N**: number of cases. Incomplete documentation involves the absence of medical investigation.

concentration do not reliably reflect cannabis dose and is poorly correlated with the severity of driving impairment. Musshoff and Madea [22] found only a weak relationship between cocaine and/or BZE blood concentration and symptoms registered by the police on the spot, and later by a medical expert. (3) On one hand, the relatively long time delay between arresting and medical investigation could have caused the complete elimination of substances with short half-life. If their metabolites are not monitored, positive cases could be missed. On the other hand, clinical symptoms may disappear between arresting and medical investigation (approximately 3 h-long period on average) resulting in false negative cases of impairment. These three together result that we have neither laboratory nor clinical basis to insist the legal impairment of the consuming driver.

### *4.1. Limitations*

Beside the deficiencies in driver testing and the unknown time-period between drug use and medical investigation this study has some more limitations. The time interval between sampling and analysis was variable depending on the availability of the laboratory. During storage, cocaine could metabolize to benzoyl-ecgonine in the blood samples and some cathinones (e.g. 4-CMC) could decompose resulting in lower concentration or false negative result [23]. Chromatographic standards were only available weeks or even months after the appearance of a new NPS which likely resulted in missed positive cases.

## 5. Conclusion

Compared to 2014–15 we did not find greater changes in the classical illicit and licit drug consumption of suspected DUID drivers. The rate of sNPS consumption for drivers tested positive markedly decreased from 22% to 8%, while SC use increased from 12% to 22%. The pattern of NPS use reflected the supply changes on the black market. In absence of impairment limits determination of impairment of single NPS users is challenging. A reconsideration of the medical investigation protocol and the reduction of time delay between arresting and sampling may prevent misjudgment of impairment. The ratio of SC users has not shown the decrease in Western European countries, so in Hungary we should follow a DUID policy concerning this tendency.

## CRediT authorship contribution statement

**László Institóris:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Előd Hidvégi:** Investigation (laboratory analysis and evaluation), Data curation. **Katalin Kovács:** Data curation, Conceptualization, Methodology, Writing – original draft. **Ákos Jámbor:** Data curation. **Adrienn Dobos:** Investigation (laboratory analysis and evaluation). **Ferenc Rárosi:** Formal (biostatistical) analysis. **Gábor Süvegh:** Investigation (laboratory analysis and evaluation). **Tibor Varga:** Supervising, Validation. **Éva Kereszty:** Conceptualization, Methodology, 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.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.forsciint.2022.111325.

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