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Prevalence of alcohol and drugs among Norwegian motor vehicle drivers: A roadside survey

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ABSTRACT

The objective of the study was to determine the prevalence of alcohol, psychoactive medicinal drugs and illegal drugs among drivers in Norwegian road traffic. Drivers of motor vehicles were selected from April 2005 to April 2006 in the south-eastern part of Norway, surrounding, but not including the capital, Oslo. A stratified two-stage cluster sampling procedure was used. In the first stage, random road sites and time intervals were selected, and in the second stage, drivers were stopped by random at those sites and time intervals. Altogether about 12,000 drivers were asked to provide a sample of oral fluid (saliva) and answer a few questions. Samples of oral fluid were obtained from 88% of the drivers, of whom 30% were females and 70% males. The prevalence of each drug was estimated by a weighted average using weights adjusted for under- or over-sampling compared to traffic statistics. Alcohol or drugs were found in oral fluid samples of 4.5% of the drivers; alcohol in 0.4%, psychoactive medicinal drugs in 3.4%, and illegal drugs in 1.0%. Illegal drugs were found more frequently in samples from younger drivers, while psychoactive medicinal drugs were more frequently found in samples from older drivers. Psychoactive medicinal drugs were more prevalent among females than males, among drivers stopped on working days rather than weekends, and among those who reported annual driving distances less than 16,000 km. The drugs found most frequently were zopiclone (1.4%), benzodiazepines (1.4%), codeine (0.8%), tetrahydrocannabinol (0.6%) and amphetamines (0.3%). Two or more drugs were found in 0.6% of the samples, corresponding to 15% of the drug-positive drivers.

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1. Introduction

It is well known that driving under the influence of alcohol or drugs increases the risk of involvement in a road traffic accident. However, compared to alcohol, less evidence is available for the accident risk related to drugs. This risk may be calculated by using data on drug prevalence in general road traffic and data on drug prevalence in drivers involved in road traffic accidents.

The prevalence of driving under the influence of drugs varies from one country to another. Reasons for the differences include different attitudes towards the use of drugs in the general populations, different use of warnings on the packaging for psychoactive medicinal drugs, differences in drug repertoires and availabilities,

different attitudes towards driving under the influence of drugs, and differently perceived or real risks of being apprehended by the police when driving under the influence.

We have observed a steady increase in the number of drugged drivers apprehended by the police in Norway since 1990 (Mørland, 2004). Approximately 5000 drivers were stopped in 2002 on suspicion of driving under the influence of drugs, approximately the same figure as the number of drivers apprehended on suspicion of drunken driving (Mørland, 2004). Medicinal or illegal drugs have also increasingly been found in blood samples from drivers killed in single vehicle accidents in Norway (Gjerde et al., 1993; Christophersen et al., 1995; Christophersen, 2005). These findings may suggest that the prevalence of driving under the influence of drugs has increased.

The aim of this study was to determine the prevalence of alcohol and potentially impairing drugs among the general driving population in Norway. The results will be used in a future study together

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with the findings on drugs from drivers killed in road accidents to estimate the traffic accident risk related to the use of different drugs.

In cases of suspected driving under the influence of drugs, blood samples are used for forensic drug analysis. However, high refusal rates have been experienced when asking for blood samples in a roadside survey in the USA (Lacey et al., 2007). The refusal rate for giving a sample of oral fluid (mixed saliva from different saliva glands) was significantly lower; oral fluid might therefore be a better choice in roadside surveys than blood samples. The use of oral fluid to detect and monitor alcohol and drug use is increasing (Caplan and Goldberger, 2001; Choo and Huestis, 2004; Cone, 2001; Samyn et al., 1999; Spiehler, 2004; Verstraete, 2005). Oral fluid is easily available using non-invasive methods. Alcohol and drugs can, in most cases, be detected in oral fluid for approximately the same length of time after consumption as in blood or for slightly longer. A fairly small amount of oral fluid is needed for the analysis of alcohol and drugs (typically 0.5–1 ml). The oral fluid sample can be collected within 1–3 min by using a simple, commercially available collection device.

2. Methods

2.1. Study design

2.1.1. Geographical area

For practical and economic reasons, the study was limited to national highways in seven counties in the south-eastern part of Norway, surrounding, but not including the capital, Oslo. These counties are covered by five Mobile Police Service districts. They have a total population corresponding to 38% of the population of Norway. Approximately 42% of the total distance driven by cars registered in Norway was driven by cars registered in these counties (Monsrud, 1997), and 42% of people killed or injured in road accidents in Norway were killed or injured in these seven counties according to Statistics Norway (<http://www.ssb.no>).

2.1.2. Data collection

Drivers of motor vehicles were selected from April 2005 to April 2006 using a stratified two-stage cluster sampling procedure. In the first stage, random road sites and time intervals were selected according to a table of random sampling numbers (Lindley and Miller, 1966). Roads were chosen by randomly selecting map coordinates, then choosing the roads closest to the selected map coordinates. Time intervals were chosen by randomly selecting a 3-day period for each police district for each month during 1 year (although this was done in such a way that two or more districts never collected data on the same dates and working hour regulations were not violated). For each day, two consecutive 4-h periods were randomly selected for sample collection at two different road sites. The police then chose the exact time and place allowing for practical considerations (e.g., choosing sites suitable as checkpoints, and ensuring acceptable driving time between consecutive checkpoint sites).

The second stage consisted of randomly stopping drivers. For each specific site and time period, a target number of drivers was determined, using official statistics of traffic volume as basis (Norwegian Public Roads Administration, 1997). The target number ranged from 15 to 60 drivers. The number of data collection personnel was related to the target numbers of drivers so that sample collection could be finished within similar time frames for each site (about 1–2 h). When the data collection personnel were ready for a new driver, the police stopped the first approaching car or motorcycle and asked for participation. When the target number had been reached for that particular site the data collection was terminated.

The data collection was carried out in cooperation with the National Mobile Police Service of Norway, which has the right to stop vehicles at random along highways without any particular suspicion. Cars were randomly stopped within the determined time periods, and the police carried out their own routine controls (e.g., breath alcohol testing or driver's licence control). Afterwards the drivers were asked to proceed to the study team, who requested voluntary and anonymous participation in the project. If informed consent was given, a sample of oral fluid was taken and a questionnaire filled in. The following data was recorded: gender, age, date, time, site, type of vehicle, and estimated annual driving distance.

In order to ensure the protection of privacy of the participants, our results were not combined with any results from police controls; hence, results from breath alcohol testing performed by the police were not included in our study. If a police officer suspected driving under the influence, one person from the data collection team went to the police van to ask for voluntary participation in our project before the suspected driver was taken to the local police station.

2.2. Biological samples

Samples of oral fluid were collected using the Intercept[®] saliva sampling kit from OraSure Technologies, Inc. (Bethlehem PA, USA). The oral fluid collection pad was placed between cheek and gums for 2 min and then transferred to the specimen vial which contained 0.8 ml of buffer. An average of 0.34 ml of oral fluid was collected, with a range from less than 0.1–1.4 ml. The vial was then capped and labelled with a bar code label identical to the bar code of the questionnaire. The sample was kept in a bag at a temperature of approximately 5 °C or in a refrigerator until analysed (normally a few days later, maximum 1 week).

2.3. Analysis of oral fluid

The amount of collected oral fluid was determined by weighing it, and the dilution with buffer was taken into account when calculating analytical results expressed in milligrams or nanograms per milliliter of undiluted oral fluid.

Alcohol was analysed by an automated enzymatic method using alcohol dehydrogenase (Kristoffersen and Smith-Kielland, 2005) with a cut-off of 0.10 mg/ml (0.10 pro-mille). The method was initially developed for the analysis of alcohol in blood and urine. Before we used it in this study, the method was validated for the analysis of alcohol in saliva diluted with buffer from the Intercept[®] saliva sampling kit. The concentration of alcohol in oral fluid is about the same as in blood (Choo and Huestis, 2004; Spiehler, 2004). The current legal driving limit for alcohol in blood in Norway is 0.20 mg/g (which is about 0.20 mg/ml in oral fluid).

Drug concentrations in oral fluid–buffer mixtures were determined by liquid chromatography–tandem mass spectrometry (Øiestad et al., 2007) and concentrations in undiluted oral fluid were calculated. The drugs analysed and the cut-off concentrations (in undiluted oral fluid) for the different substances are presented in Table 1.

The cut-off limits for medicinal drugs were set to exclude individuals who had drug concentrations in their oral fluid reflecting low therapeutic blood concentrations that were not expected to affect driving safety. The cut-off limits for illegal drugs were set to exclude subjects who had drug concentrations in their oral fluid reflecting low blood concentrations or non-recent drug intake that were not expected to affect driving safety significantly. Where applicable, cut-off concentrations were used equal to those in the ongoing DRUID project (Pil and Verstraete, 2007), except for low-dose benzodiazepine hypnotics where lower cut-off concentrations

Table 1
Substances analysed, cut-off limits, prevalence (weighted %), and 95% confidence intervals (CI)

Substance	Description	Cut-off (ng/ml)	%	95% CI
Alcohol (ethanol)	Legal limit for driving in Norway: 0.2 mg/g in blood	0.1 mg/ml	0.37	0.18–0.59
Alprazolam	Benzodiazepine; anxiolytic	1	0.04	0.00–0.10
Amphetamine	Stimulant. Used to treat attention-deficit hyperactivity disorder (ADHD), symptoms of traumatic brain injury, narcolepsy and chronic fatigue syndrome. Mostly used illegally in Norway	25	0.26	0.14–0.42
Bromazepam	Benzodiazepine; sedative, hypnotic, anxiolytic, skeletal muscle relaxant	8	0	
Buprenorphine	Opioid analgesic. Treatment of heroin addiction	1.2	0.02	0.00–0.08
Carisoprodol	Muscle relaxant	50	0.07	0.01–0.16
Meprobamate	Metabolite of carisoprodol	1000	0.17	0.07–0.30
Cariso. or meprobamate	–	–	0.19	0.08–0.33
Clonazepam	Benzodiazepine; anticonvulsant, anxiolytic	0.5	0.05	0.01–0.12
7-Aminoclonazepam	Degradation product and metabolite of clonazepam	0.7	0.06	0.01–0.13
Clonaz. or 7-aminocl.	–	–	0.09	0.03–0.17
Cocaine	Stimulant; illegal in Norway.	10	0.04	0.00–0.09
Benzoylcegonine	Degradation product and metabolite of cocaine	10	0.11	0.03–0.22
Cocaine or benzoylceg.	–	–	0.12	0.04–0.24
Codeine	Opiate analgesic, antitussive, antidiarrheal properties	20	0.76	0.55–1.00
Diazepam	Benzodiazepine; anxiolytic, anticonvulsant, sedative, skeletal muscle relaxant	1	0.61	0.41–0.83
Nordiazepam	Psychoactive metabolite of diazepam	1	0.76	0.53–1.01
3-Hydroxydiazepam	Metabolite of diazepam	1.5	0	
Diazepam or metabolites	–	–	0.80	0.57–1.05
Flunitrazepam	Benzodiazepine; hypnotic.	0.3	0.03	0.00–0.11
7-Aminoflunitrazepam	Degradation product and metabolite of flunitrazepam	0.3	0.08	0.01–0.18
Flu. or 7-aminoflu.	–	–	0.08	0.01–0.18
Lorazepam	Benzodiazepine; sedative, hypnotic, muscle relaxant, anxiolytic, anticonvulsant	1.6	0	
Lysergic acid diethylamide	Illegal psychedelic, hallucinogenic drug (LSD)	0.16	0	
Methadone	Opiate analgesic. Treatment of heroin addiction	20	0.03	0.00–0.08
Methamphetamine	Stimulant. Illegal in Norway	25	0.12	0.04–0.23
3,4-Methylenedioxy-N-ethylamphetamine	Illegal psychedelic hallucinogenic drug (MDEA)	25	0	
3,4-Methylenedioxy-N-methylamphetamine	Illegal psychedelic hallucinogenic drug (MDMA)	25	0	
6-Monoacetylmorphine	Degradation product and metabolite of heroin, only illegal use in Norway	5	0.01	0.00–0.03
Morphine	Opiate analgesic. Also metabolite of codeine and heroin	10	0.08	0.02–0.16
Nitrazepam	Benzodiazepine; hypnotic	0.5	0.11	0.03–0.21
7-Aminonitrazepam	Degradation product and metabolite of nitrazepam	0.7	0.12	0.04–0.22
Nitraz. or 7-aminonitr.	–	–	0.14	0.05–0.25
Oxazepam	Benzodiazepine; anxiolytic, anticonvulsant, sedative skeletal muscle relaxant	5	0.24	0.11–0.40
Phenazepam	Benzodiazepine; anticonvulsant, hypnotic, and during alcohol withdrawal	0.9	0	
Tetrahydrocannabinol	Cannabis, hashish, marijuana. Illegal in Norway	1	0.60	0.40–0.84
Zolpidem	Short-acting non-benzodiazepine hypnotic	10	0.02	0.00–0.06
Zopiclone	Short-acting non-benzodiazepine hypnotic	10	1.42	1.12–1.76

were used in our study to include subjects who had used normal therapeutic doses of these particular drugs.

2.4. Statistical analysis

The aim of the study was to estimate the prevalence of various drugs among drivers across all journeys in the five police districts over a year. By design, the sample data were representative for the whole year, but certain days within a week or hours within the day could be under- or over-sampled compared to the overall distribution of traffic volume. Furthermore, the sample sizes were roughly the same for the five police districts, whereas their proportions of the total traffic volume varied between 11% and 25%. Therefore, the prevalence of each drug was estimated by a weighted average, using weights adjusted for under- or over-sampling of the data compared to overall traffic statistics (Vågane, 2005; Norwegian Public Roads Administration, 1997). Hence, the weighted sample of drivers matched approximately the overall distribution of the traffic vol-

ume between police districts, the days in a week and the hours of the day.

The weighted prevalence was calculated as follows: let p_a be the reported proportion of traffic volume in police district a , $a = 1, \dots, 5$. The five p_a 's add to 1. Furthermore, let n be the total sample size, and n_a the sample size in police district a . Preliminary weights w_a were calculated such that the distribution between police districts in the weighted sample matched the reported proportion, i.e. $w_a n_a / n = p_a$, giving $w_a = p_a n / n_a$. Similarly, preliminary weights v_b , $b = 1, \dots, 7$ for days in a week and u_c , $c = 1, \dots, 24$ for hours of the day were calculated. The final weights for all drivers sampled in police district a , weekday b and hour c were given by $w_a v_b u_c$. With these combined weights, the distribution within the weighted sample did not match the reported distribution exactly, but the approximation was close. Finally, let y_{abcd} indicate the result of a drug test on the d th sampled driver in police district a weekday b and hour c , y_{abcd} being 1 if the test is positive and 0 if it is negative. The prevalence of the drug was then estimated by $\sum_{abcd} (w_a v_b u_c y_{abcd}) / \sum_{abcd} (w_a v_b u_c)$.

Table 2
Substance findings (weighted %) in relation to gender, 95% confidence intervals (CI), differences between men and women, and *p*-values

Substance findings	Total	95% CI	Men	95% CI	Women	95% CI	Difference	<i>p</i>
Total alcohol or drugs	4.5	3.9–5.1	4.2	3.5–4.8	5.2	4.1–6.3	–1.0	0.12
Alcohol	0.4	0.2–0.6	0.4	0.2–0.7	0.2	0.0–0.6	0.2	0.35
Psychoactive medicinal drugs	3.4	2.9–3.9	3.0	2.4–3.5	4.3	3.3–5.4	–1.4	0.02
Zopiclone	1.4	1.1–1.8	1.1	0.8–1.5	2.1	1.4–2.9	–1.0	0.02
Benzodiazepines	1.4	1.0–1.7	1.2	0.9–1.6	1.6	1.0–2.2	–0.4	0.33
Diazepam/nordiazepam	0.8	0.6–1.1	0.7	0.4–1.0	1.1	0.6–1.6	–0.4	0.14
Codeine	0.8	0.6–1.0	0.7	0.4–1.0	0.9	0.5–1.4	–0.2	0.45
Illegal drugs	1.0	0.7–1.3	1.1	0.8–1.5	0.8	0.4–1.2	0.4	0.20
Tetrahydrocannabinol	0.6	0.4–0.8	0.7	0.4–1.0	0.4	0.2–0.8	0.3	0.17
Amphetamines	0.3	0.2–0.5	0.4	0.2–0.6	0.1	0.0–0.3	0.3	0.04
Cocaine/benzylecgonine	0.1	0.0–0.2	0.1	0.0–0.2	0.2	0.0–0.5	–0.2	0.23
Total no. of samples analysed	10,816*		7577		3237			

* Gender not recorded in two cases.

Confidence intervals (95%) and *p*-values were calculated by a two-stage bootstrap procedure using the percentile interval method (Efron and Tibshirani, 1993), mimicking the sampling design, and constructing 5000 resamples of the observed dataset by random sampling with replacement from the original dataset.

Computations were done using The R software, Version 2.6.1 and the Statistical Package for Social Sciences (SPSS), Version 14.0 for Windows.

3. Results

3.1. Overview

A total of 10,835 drivers of motor vehicles agreed to participate in the study, while 1479 (12%) drivers refused. The data collection time at the sampling sites was 88 ± 32 min (average \pm standard deviation) with a range from 19 to 250 min, which for collection periods of more than 2 h included a resting period of 30–60 min.

In some cases, the sample volumes were insufficient for analysis of both drugs and alcohol. In those cases, the analysis of drugs was prioritised. So, 10,816 samples were analysed for drugs and 10,793 for alcohol.

Thirty percent of the drivers included in the study were female while 70% were male, which roughly corresponds to drivers in general road traffic (Vågane, 2005).

Alcohol or drugs were found in 4.5% (weighted percentage) of the samples, and details are presented in Table 1. The most

commonly detected drugs were zopiclone, codeine, diazepam/nordiazepam, THC, and amphetamine.

Psychoactive medicinal drugs (including morphine but excluding cases where morphine was present as a result of heroin use confirmed by the presence of 6-monoacetylmorphine) were found in 3.4% of the drivers, and illegal drugs in 1.0%.

Substance findings in relation to gender, weekend or working day, and for different substance groups are presented in Table 2 and Table 3. The prevalence of psychoactive medicinal drugs was higher among females than males ($p = 0.02$), while the prevalence of illegal drugs seemed to be higher among males (although not statistically significant; $p = 0.20$). The prevalence of psychoactive medicinal drugs was higher on working days than at weekends ($p = 0.02$).

Alcohol and drug findings in relation to the age of the driver are presented in Table 4. Illegal drugs were more frequently found in the oral fluid of younger drivers, while psychoactive medicinal drugs were more often found in the oral fluid of older drivers. At night-time (between 22:00 and 04:00 h), the prevalence of illegal drugs among drivers below 35 years of age was 4.6% (results not shown). The prevalence of psychoactive medicinal drugs increased with age, and the highest prevalence was found among older female drivers; drugs were found in 8.1% of female drivers aged 55–64 years and 11.3% of female drivers over 64 years of age (results not shown).

The prevalence of drugs or alcohol was lower among those who reported a large annual driving distance. Alcohol or drugs were found in oral fluid samples of 6.1% of the drivers who reported annual driving distances up to 16,000 km and in 3.3% of the drivers

Table 3
Substance findings (weighted %) for working days, weekends, 95% confidence intervals (CI), differences between working days and weekends, and *p*-values

Substance findings	Working day	95% CI	Weekend	95% CI	Difference	<i>p</i>
Total alcohol or drugs	4.8	4.1–5.6	3.8	2.9–4.8	1.0	0.09
Alcohol	0.5	0.2–0.8	0.2	0.0–0.4	0.3	0.10
Psychoactive medicinal drugs	3.8	3.1–4.4	2.6	1.9–3.4	1.2	0.02
Zopiclone	1.6	1.2–2.0	1.1	0.7–1.5	0.5	0.13
Benzodiazepines	1.5	1.1–1.9	1.1	0.6–1.6	0.4	0.24
Diazepam/nordiazepam	0.8	0.6–1.2	0.7	0.3–1.1	0.2	0.46
Codeine	0.9	0.6–1.2	0.5	0.2–0.8	0.4	0.05
Illegal drugs	0.9	0.6–1.3	1.2	0.8–1.7	–0.3	0.36
Tetrahydrocannabinol	0.6	0.3–0.9	0.7	0.4–1.1	–0.1	0.60
Amphetamines	0.2	0.1–0.4	0.4	0.2–0.8	–0.2	0.33
Cocaine/benzylecgonine	0.1	0.0–0.3	0.1	0.0–0.3	0.0	0.95
Total no. of samples analysed	6718		4098			

Table 4
Substance findings (weighted %) in relation to age group (years), both genders combined

Substance findings	<25	25–34	35–44	45–54	55–64	>64
Total alcohol or drugs	2.1	3.4	3.4	4.0	6.6	8.5
Alcohol	0.2	0.4	0.4	0.4	0.5	0.0
Psychoactive medicinal drugs	0.5	1.6	2.3	3.1	5.8	8.2
Zopiclone	0.0	0.3	0.9	1.3	2.6	4.3
Benzodiazepines	0.4	0.7	0.8	1.2	2.5	3.0
Diazepam/nordiazepam	0.3	0.4	0.4	0.7	1.6	1.6
Codeine	0.1	0.3	0.5	1.1	1.2	1.1
Illegal drugs	1.8	1.9	1.1	0.7	0.4	0.2
Tetrahydrocannabinol	1.5	1.4	0.5	0.4	0.1	0.1
Amphetamines	0.1	0.5	0.4	0.3	0.3	0.1
Cocaine/benzylecgonine	0.1	0.1	0.3	0.0	0.1	0.1
Total no. of samples analysed	1010	1855	2525	2434	1978	1012

who reported an annual driving distances greater than 16,000 km (results not shown).

The findings of psychoactive medicinal drugs are compared with data from the Norwegian Prescription Database on the prescription of these drugs (Rønning, 2007) as measured by defined daily doses (DDD), which is defined as the assumed average maintenance dose per day for a drug used on its main indication in adults; see Table 5. The findings of psychoactive medicinal drugs correlate fairly well with the DDD data.

3.2. Alcohol

Alcohol above the cut-off of 0.1 mg/ml was found in 0.4% of the samples. In 0.3% of the oral fluid samples, alcohol concentration was above 0.2 mg/ml, and in 0.1% above 0.5 mg/ml. Alcohol only was found in 0.3% of the samples.

3.3. Non-benzodiazepine hypnotics

Zopiclone is the most commonly prescribed sleeping tablet in Norway. Zopiclone was found in oral fluid from 1.4% of the drivers (weighted percentage). The prevalence of zopiclone was higher among female than male drivers ($p=0.02$).

Zolpidem is very much less frequently prescribed than zopiclone, and was found in oral fluid samples from only 0.02% of the drivers.

3.4. Benzodiazepines

Benzodiazepines are mainly used to treat anxiety or sleeping problems. Altogether, 1.4% of the samples of oral fluid were found to contain concentrations of benzodiazepines above the cut-off values. Diazepam, which is mainly prescribed for its sedative and anxiolytic properties, was the most frequently found benzodi-

azepine. Diazepam or its principal metabolite nordiazepam, which is also a psychoactive substance, were found in 0.8% of the samples (weighted percentage).

Oxazepam, which is sedative and anxiolytic, is less frequently prescribed, and higher doses than diazepam are used. Oxazepam was detected in 0.2% of the samples.

Nitrazepam and flunitrazepam are used as hypnotic agents. They could degrade in samples of saliva during storage, so the degradation products 7-aminonitrazepam and 7-aminoflunitrazepam were also analysed. Altogether the nitrazepam and flunitrazepam (including degradation products) were each found in 0.1% or fewer of the samples.

3.5. Carisoprodol and meprobamate

Carisoprodol is used as a muscle relaxant, while meprobamate is a psychoactive metabolite of carisoprodol. Meprobamate itself is used as a sedative, anti-anxiety agent, muscle relaxant and for treating migraine. In Norway, carisoprodol was prescribed fairly frequently until 2007, while medicinal drugs containing meprobamate are rarely prescribed. Therefore, the vast majority of meprobamate-positive cases were due to use of carisoprodol. Meprobamate was detected in 0.2% of the drivers while carisoprodol was detected in about half of the meprobamate-positive samples of oral fluid.

3.6. Opioid analgesics

Codeine, which is used for the relief of mild to moderately severe pain, was the most commonly detected opioid. It was found in oral fluid of 0.8% of the drivers. Codeine was found less frequently on weekdays than at weekends ($p=0.05$).

Morphine, methadone and buprenorphine were each found in about 0.1% of the samples of oral fluid.

Table 5
Comparison of the prevalence (weighted %) of psychoactive medicinal drugs among drivers and defined daily doses (DDD) in the total population (Rønning, 2007)

Medicinal drug	Prevalence (%)	DDD 2006/100 inhabitants/day
Zopiclon	1.42	3.098
Diazepam (including nordiazepam)	0.80	1.042
Codeine	0.76	1.284
Oxazepam	0.24	0.711
Carisoprodol (including meprobamate)	0.19	0.211
Nitrazepam (including 7-aminonitrazepam)	0.14	0.575
Clonazepam (including 7-aminoclonazepam)	0.09	0.071
Flunitrazepam (including 7-aminoflunitrazepam)	0.08	0.198
Alprazolam	0.04	0.215
Zolpidem	0.02	0.356

3.7. Tetrahydrocannabinol

Tetrahydrocannabinol (THC) is the most active of the principal constituents of marijuana. THC was found in 0.6% of the samples, most frequently in younger drivers.

3.8. Stimulants

Amphetamine and/or methamphetamine concentrations above the cut-off were observed in 0.3% of the samples; both amphetamine and methamphetamine were found in 0.1%. Amphetamines are rarely prescribed to adults, so practically all subjects using amphetamines are assumed to have obtained these substances illegally.

Cocaine and/or the degradation product benzoylecgonine were detected in 0.1% of the samples.

3.9. Combinations of alcohol and/or drugs

Alcohol or drugs were found in 4.5% of the samples. Alcohol combined with drugs was rarely found, only in 0.04% of the cases. Two or more drugs were found in 0.6% of the samples, corresponding to 15% of the drug-positive cases. There were no marked differences in multi-drug use between different age groups.

4. Discussion

This roadside study was organised in collaboration with the Mobile Police Service who stopped drivers randomly at pre-determined sites and in pre-determined numbers for compulsory breath testing or other types of police control. After completing the police control, each driver was asked to participate voluntarily in our anonymous study. Twelve percent refused to participate. This is a significant proportion of the drivers, and it might be reasonable to assume that a higher percentage of those who refused had used alcohol or drugs prior to driving.

A Belgian study found that the prevalence of drink drivers at a control site decreased over time, probably because drivers passing the control site warned other drivers (Vanlaar, 2005; Vanlaar, 2008). If police officers continued to check drivers for more than an hour at the same road site, the final sample of drivers selected at that site would thus most likely be biased (Vanlaar, 2005). In our study, samples were on average collected for 88 min at the road control site in order to include a sufficient number of drivers. Due to fairly long control periods the observed prevalence of alcohol and drugs might be somewhat lower than in random traffic.

Alcohol and most drugs enter oral fluid from the blood by a passive diffusion process dependent on the compound's properties (Crouch, 2005; Samyn et al., 1999). Significant inter- and intra-subject variability in oral fluid/blood ratios has been observed (Crouch, 2005). For some drugs, oral fluid may give false negative results compared to blood; and small sample volumes might also cause false negative results. The route of drug administration (orally, intravenously, nasally, or by smoking) and the sampling method for oral fluid may also affect the drug concentration in the oral fluid sample. For these reasons, concentrations of drugs in oral fluid must be interpreted with care. From a legal point of view, the detection of a drug in oral fluid may only be used to confirm the intake of that particular drug, and not to indicate impairment since it is impossible to estimate the blood drug concentration with acceptable accuracy using the concentration in oral fluid. In epidemiological studies such as this, however, individual variations are of less importance, and drug concentrations in oral fluid can provide valuable information.

The prevalence of alcohol above 0.5 mg/ml in oral fluid (corresponding to about 0.5 mg/g in blood) found in this study was 0.1%, which is lower than observed in an earlier roadside study carried out in 1981–1982 (Glad, 1985). In that study, which used random breath alcohol controls performed by the police, and which drivers were not allowed to refuse, 0.27% of the drivers were found to have breath alcohol levels reflecting blood concentrations above 0.5 mg/g. After that study, the legal limit for blood alcohol concentrations has been lowered from 0.5 to 0.2 mg/g, and the prevalence of driving under the influence of alcohol might have been affected by the new limit.

In a few cases (corresponding to a maximum of 0.1% of the drivers) the police officer concerned did not refer clearly drunken drivers to saliva sampling. These individuals were taken immediately to the police station for evidential breath testing or blood sampling and this removed them from our study population. In addition, the prevalence of alcohol among drivers in this study was low compared to the refusal rate. It is likely, therefore, that the prevalence of alcohol-positive drivers in random traffic is somewhat higher than we observed, and it is not possible to conclude from these results whether the prevalence of drunken driving has actually changed since 1981–1982.

In Norway, the packaging of psychoactive medicinal drugs that might affect driving performance, are marked with a red triangle, and the package inserts include a warning that the ability to drive or work safely might be impaired by taking the drug. In spite of this warning, medicinal drugs that might affect driving performance were found in the oral fluid samples from 3.4% of the drivers.

The analytical cut-off values for medicinal drugs were set to exclude subjects with low drug concentrations that were unlikely to affect driving ability. For benzodiazepines, the concentrations in oral fluid are much lower than in blood (Spiehler, 2004; Moschitto and Greenblatt, 1983). For flunitrazepam, which is a low-dose benzodiazepine used as sleeping agent, the result for oral fluid might be negative even if the blood contains therapeutic concentrations. For sleeping agents, even low therapeutic concentrations may adversely affect driving. An additional problem is that some benzodiazepines are unstable in saliva and might degrade after sampling of oral fluid. Finally, some potentially impairing drugs that are used infrequently were not analysed. Some of these might also have been present in impairing concentrations without being detected. For these reasons, the prevalences of drugs we report are minimum figures.

The hypnotic drug zopiclone was the most frequently detected, followed by benzodiazepines and codeine. This correlates well with the sales data for those drugs. However, for drugs with very short half-life, such as zolpidem and alprazolam, the prevalence in oral fluid among drivers was fairly low compared to the DDD, because these drugs could be detected for a fairly short time period after use. The high prevalence of psychoactive medicinal drugs among older drivers compared to other age groups reflects the pattern of therapeutic use in the population according to the Norwegian prescription database (<http://www.norpd.no>).

It is well-known that cannabis is the most frequently used illegal drug in the general population in Norway, and amphetamines are more frequently used than cocaine. This is reflected in our findings. The high prevalence of illegal drugs compared to alcohol was somewhat unexpected.

Previously oral fluid has been analysed in roadside studies in Australia (Drummer et al., 2007; Starmer et al., 1994), Germany (Krüger et al., 1995), Denmark (Behrensdoerff and Steentoft, 2003), Scotland (Assum et al., 2005; Wylie et al., 2005), and Norway (Assum et al., 2005). However, comparison with those studies is difficult because of different analytical methods, different analytical cut-off concentrations, and different oral fluid sampling techniques.

In the previous Norwegian study, only 410 samples of oral fluid were analysed (Assum et al., 2005). Only 1% of the samples (weighted prevalence) had drug concentrations above the cut-off values used. Breath alcohol was tested, and nobody was positive.

The prevalence of drug findings in our study is somewhat higher than those found in a Danish roadside study (Behrendorf and Steentoft, 2003) in which 961 samples of oral fluid were collected, but because of small sample volumes 65 samples were not analysed. After screening and confirmation analysis, 0.8% were positive for THC, 0.7% for benzodiazepines, 0.3% for opiates, and 0.2% for stimulants (weighted percentages). The number of detected benzodiazepine cases was low because the screening technique did not include some of the frequently used low-dose benzodiazepines, and the prevalence of zopiclone was not determined. The authors stated that it was difficult to assess the proportion of impaired drivers based on the analytical results. However, a conservative estimate was that half of the drug-positive drivers (i.e. 1% of the drivers studied) were impaired to a degree that might have been of importance to road safety.

In the German roadside study, performed in 1992 (Krüger et al., 1995), samples of oral fluid were obtained from 12,213 drivers. Due to financial constraints only 2235 of these samples were analysed. Only immunological methods were used, so the analyses were not as accurate and specific as for the chromatographic methods employed in the Danish study and in our study, and for some benzodiazepines the immunological method was probably not very sensitive. After weighting the results for age, gender, time of day and day of week the prevalence of alcohol >0.3 g/l was 2.01%, and the prevalence of benzodiazepines (≥ 3 ng/ml) was 3.64%, opiates 0.70%, cannabinoids 0.61%, and barbiturates 0.53%. So, in Germany the prevalence of alcohol was markedly higher than in Norway, as was the prevalence of benzodiazepines and barbiturates, whereas the prevalence of opiates was lower. Krüger et al. concluded that the drug concentrations observed were likely to induce safety problems in one tenth of the cases where legal drugs were found and one third of cases where illegal drugs were found. This implies that around 0.7% of the drivers had drug concentrations that were likely to cause impairment.

In the Australian studies, higher prevalences of cannabis and amphetamines were observed than in our material (Starmer et al., 1994; Drummer et al., 2007), while in Scotland 16.8% were found to be positive for one or more drugs of which MDMA (Ecstasy) and cannabis were most frequently found (Assum et al., 2005; Wylie et al., 2005).

The results of our study indicate that a significant proportion of randomly tested drivers in Norway had used medicinal drugs or illegal drugs that could impair driving. Psychoactive medicinal drugs were significantly more prevalent than alcohol and illegal drugs. We have previously observed an increase in the apprehension of drugged drivers by the police in Norway (Mørland, 2004), and our findings suggest that in Norwegian road traffic drugged driving might have become a bigger problem than drunken driving. We will be carrying out further studies to estimate the traffic accident risks associated with the drugs found.

It is very difficult to estimate the prevalence of impairment in the driving population solely using drug concentrations in oral fluid. The total prevalence of drugs among Norwegian drivers was somewhat higher than found in the Danish and German studies. Taking into account the differences in drug findings and analytical methodology, we believe that the prevalence of impaired driving might be similar to the results from Denmark (about 1%). Further investigations are needed before we can make a more accurate estimate of the prevalence of impaired driving using analytical results from oral fluid.

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