Association between speeding and use of alcohol, medicinal and illegal drugs and involvement in road traffic crashes among motor vehicle drivers.

Benedicte Jørgenrud[1], Stig Tore Bogstrand[1], Håvard Furuhaugen[1], Ragnhild E. G. Jamt[1,2], Vigdis Vindenes[1,3], Hallvard Gjerde[1]

[1]Department of Forensic Sciences, Oslo University Hospital, Oslo, Norway

[2]Institute of Health and Society, University of Oslo, Oslo, Norway

[3]Institute of Clinical Medicine, University of Oslo, Oslo, Norway

Address correspondence to:

Benedicte Jørgenrud

Department of Forensic Sciences

Oslo University Hospital

P.O. Box 4950 Nydalen

NO-0424 Oslo

Norway

E-mail: bemjoe@ous-hf.no

ABSTRACT

Objective: To study the association between self-reported road traffic crashes (RTCs) and recent use of alcohol, medicinal and illicit drug use and self-reported speeding the previous two years.

Methods: During the period from April 2016 to April 2017, drivers of cars, vans, motorcycles and mopeds were stopped in a Norwegian roadside survey performed in collaboration with the police. Participation was voluntary and anonymous. The drivers were asked to deliver an oral fluid sample (mixed saliva), which was analyzed for alcohol and 39 illicit and medicinal drugs and metabolites. In addition, data on age, sex, and self-reported speeding tickets and RTCs during the previous two years were collected.

Results: A total of 5031 participants were included in the study, and 4.9% tested positive for the use of one or more illicit or medicinal drug or alcohol. We found a significant, positive association between the use of cannabis and RTC involvement (OR=1.93, 95% CI=1.05-3.57, p=0.035) and also between previous speeding tickets and RTC involvement (OR=1.39, 95% CI=1.08-1.80, p=0.012). In addition, older age groups were found to have a significant, negative association with RTC involvement, with ORs equal to or less than 0.49, when using age group 16-24 as reference.

Conclusion: Speeding, as an indicator of risk behavior, and the use of cannabis was associated with previous RTC involvement, while increasing age was significantly associated with lower risk. This is consistent with previous studies on RTCs.

KEY WORDS: Roadside survey, oral fluid, alcohol, drugs, speeding, road traffic crashes

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INTRODUCTION

Speeding and driving under the influence (DUI) of alcohol or drugs are among the highest risk factors for involvement in road traffic crashes (RTCs). DUI of alcohol or drugs may be associated with impaired attention, increased reaction time and increased risk-taking, among other things (Ogden & Moskowitz 2004; Penning et al. 2010). In Norway, it has been illegal to drive under the influence of alcohol since 1912. However, the first legal limit was implemented in 1936, with a limit for DUI of alcohol of 0.5 g/kg in blood. Since then, the legal limit of DUI of alcohol was reduced to 0.2 g/kg in 2001, and per-se limits were implemented for DUI for 28 illicit and medicinal drugs in 2012/2016 (Vindenes et al. 2015; Vindenes et al. 2012). In addition to strict DUI regulations, speed limit is an important measure for sustaining the safety of road users. Norway was among the first countries in the world to set speed limits already in 1912, and is among the countries in Europe with the lowest speed limits, with the aim of reducing the number of RTCs.

Despite of strict legislation in Norway concerning DUI of drug and alcohol and speeding, there were still 106 fatal RTCs in Norway in 2017, whereof 72 of the fatalities were drivers or motorcycle riders (Statistics Norway 2018). In the same year, 667 persons were severely injured in RTC, whereof 378 were drivers or riders (Statistics Norway. 2018). Even though the number of fatal crashes is steadily decreasing, the number of severe injury in car crashes appears to have stabilized over the last few years. Investigations of fatal RTCs in Norway during 2005-14 found that 42% of the crashes were related to speeding, while the use of alcohol or drugs was documented in 21% of the crashes (Haldorsen 2015); the actual proportion is probably higher as one third of fatal crashes are not investigated for alcohol or drug use (Christophersen & Gjerde 2014; Skjønborg et al. 2015). Previous studies have also found that drivers under the influence of alcohol generally had higher speed when crashing compared to sober drivers (Bogstrand et al. 2015; NHTSA 2009; Phillips & Brewer 2011; Stubig et al. 2012). Although the risk of being killed in traffic in Norway is among the lowest in the world (World Health Organization 2017), Norwegian government implemented a “Vision Zero” in 2001, with the aim of working towards a future with no fatalities or serious injuries in RTCs (Elvebakk & Steiro 2009).

Driver personality may predict risky driving behavior, which again may increase the risk of RTC involvement (Elander et al. 1993; Lucidi et al. 2014; Yang et al. 2013). Speeding may be regarded as an indicator of risk-taking behavior (Golias & Karlaftis 2001; Iversen 2004), which can be linked to sensation seeking (Zuckerman & Neeb 1980). Associations have also been found between sensation seeking or risk-taking personality and the use of illicit drugs (Donohew et al. 1999a; Donohew et al. 1999b) and alcohol (Earleywine & Finn 1991; Earleywine et al. 1990; Shapiro & Kim 2002). These are substances, which themselves may increase risk-taking behavior.

It has also been proposed that attitudes and subjective norms may predict certain behaviors (Ajzen & Fishbein 1980; Fishbein & Ajzen 1975). The perceived behavioral control (PBC) may be a third predictor of behavior, as described in the theory of planned behavior (TPB) (Ajzen 1985; Ajzen 1991). In several studies where TPB was applied to predict the intention to exceed speed limits, it was found that attitude, subjective control and PBC can be used to predict the intention (Conner et al. 2007; Elliott et al. 2003; Letirand & Delhomme 2005). Speeding may thus often be a result of several factors related to personality, subjective norms and attitudes, as well as perceived subjective control.

The literature on the association between speeding, DUI and RTC is primarily based on studies on fatal crashes. We therefore wanted to investigate the association between speeding and DUI on RTC risk in normal road traffic.

We hypothesize that, in spite of strict speed limits and DUI limits implemented to reduce the number of RTCs, speeding as an indicator of risk-taking behavior and DUI of alcohol and drugs are still predominant risk factors for RTCs. The aim of this study was to investigate the association between the use of alcohol or drugs before driving, self-reported speed violations, and self-reported RTC involvement among drivers in random road traffic.

METHODS

Study design

A cross-sectional study was performed in the Norwegian counties of Oslo, Akershus, Buskerud, Hedmark and Oppland. The aim was to collect anonymous survey data and oral fluid (mixed saliva) samples from volunteer drivers of cars, vans, motorcycles and mopeds stopped by the Norwegian Mobile Police Service and the Road Traffic Department in Oslo Police District.

Participants

The sampling was performed from April 2016 to April 2017, as described by Furuhaugen et al. (2018). The participants were asked to deliver an oral fluid sample and answer a survey regarding speeding tickets and involvement in RTCs during the last two years.

Variables

As part of the survey, we collected information about the sex and age group of the participants, and we asked if they had been given a ticket for speeding or been involved in any RTCs the previous two years.

Oral fluid analyses

Oral fluid samples were collected from the participants using Quantisal™ Oral Fluid Collection Device (Immunalysis Corporation, Pomona, CA, USA) as described by Furuhaugen et al. (2018). An automated enzymatic method using alcohol dehydrogenase, as described by Kristoffersen & Smith-Kielland (2005), was used for alcohol analysis. Analysis of illicit and medicinal drugs was performed using ultra-performance-liquid chromatography coupled with tandem mass spectrometry, as described by Furuhaugen et al. (2018), who also listed the cutoff limits for each compound. All analyses were performed at the laboratory of the Department of Forensic Sciences at Oslo University Hospital.

Statistical analyses

Pearson's chi-square test was used to test for associations between self-reported speeding tickets and the use of illicit and medicinal drugs and alcohol. We decided to divide illicit drugs into cannabis (tetrahydrocannabinol; THC) and stimulants (amphetamines, cocaine or benzoylecgonine), and medicinal drugs into opioid analgesics (morphine, codeine, tramadol, buprenorphine or methadone) and sedatives and hypnotics (benzodiazepines with

some metabolites and z-hypnotics) to investigate which groups of illicit drug or medicinal drug might be associated with previous speeding tickets. We also wanted to test if there was an association between speeding tickets, the use of alcohol, illicit and medicinal drugs (and groups of drug) and self-reported RTCs. The alpha value was set at 0.05.

To test for associations between self-reported RTC involvement, speeding tickets and the use of illicit drugs, medicinal drugs and alcohol, we employed multivariable logistic regression analysis. Self-reported RTC was used as dependent variable and self-reported speeding tickets and the use of alcohol and different groups of illicit and medicinal drugs were used as independent variables together with sex and age group, regardless whether any of the variables was statistically significantly associated with the dependent variable or not. Interactions between independent variables were studied.

All statistical analyses were performed using SPSS® Statistics version 23 (IBM Corporation, Armonk, NY).

Ethics

The study was approved by the Regional Committee for Medical and Health Research Ethics, approval no. 2015/2092.

RESULTS

A total of 5556 drivers of cars, vans, motorcycles and mopeds were stopped and asked to participate in this study, whereof 518 drivers (9.3%) declined to participate, and four participants delivered oral fluid samples with insufficient volume and were subsequently excluded. The total number of participants who delivered oral fluid samples was 5034. Further, two participants were excluded because their age was not recorded, and one participant because sex was not recorded, resulting in a dataset of 5031 participants.

As Table 1 shows, there was a higher percentage of men compared to women among the participants (67.2% vs 32.8%), and the mean age was approximately the same for men as for women (45.9 and 44.1, respectively). Generally, men reported higher number of RTCs and speeding tickets the previous two years compared to women (76.1% vs 23.9%, and 70.4% vs 29.6%, respectively).

Analyses of oral fluid samples from the 5031 participants found 298 positive substance detections. However, several participants tested positive for more than one compound, resulting in 4.9% of the participants testing positive for one or more illicit drug, medicinal drug or alcohol. A total of 1.4% of the participants tested positive for THC, indicating recent use of cannabis, with a larger proportion of those being men (84.7%). There were also more men among those testing positive for other illicit drugs, mainly stimulants. Of the medicinal drugs, 1.1% of the participants tested positive for opioid analgesics, and these were predominantly men. Within the opioid analgesics, most drivers tested positive for codeine and tramadol, with the sex-distribution being almost the same within the users of these substances (data not shown). Sedatives and hypnotics were the only subgroup of drugs where the users were predominantly women. A more detailed overview of sex-distribution of each illicit and

medicinal drug, together with cutoff limits, has been published by Furuhaugen et al. (2018). The cutoff limits used in this study are the same as those used in a previous roadside study (Gjerde et al. 2013), except that some additional substances were included; this included tramadol because of increased number of prescriptions, phenobarbital because it is commonly used in a neighboring country, fentanyl because of increasing misuse, and ten of the most likely used New Psychoactive Substances. Findings of alcohol or drugs were categorized as positive if above the cutoff concentrations, and reflected use of alcohol or single doses for most drug types during the last 1-2 days. For chronic users of some drugs, oral fluid sample may test positive for more than two days after the last intake.

Bivariate analyses (Table 2) showed that the use of any illicit drug had a significant, positive association with self-reported speeding tickets (p=0.008). However, when sub-dividing illicit drugs into cannabis and stimulants separately, there was no significant association with self-reported speeding tickets (p=0.105 and 0.063, respectively).

A larger proportion of those reporting to have been speeding also reported to have been involved in RTCs compared to those who did not report speeding (p=0.002). Also the use of any illicit and medicinal drugs was significantly associated with self-reported RTC involvement (p=0.004 and p=0.009, respectively), with participants testing positive for illicit drugs reported to have been in RTCs more frequently compared to those testing negative for the use of any illicit drugs (17.2% vs 8.6%), while participants testing positive for the use of medicinal drugs reported to have been involved in RTCs less frequently compared to those that tested negative for the use of medicinal drugs (2.8% vs 9.0%). The use of cannabis was found to be significantly associated with reported RTCs, with users having been in crashes more often than non-users (p<0.001), while the use of sedatives and hypnotics confers a lower risk for having been in RTCs compared to those not using those substances (1.9% vs 8.9%, p=0.012).

Crude and adjusted ORs for RTCs are presented in Table 3, showing that there was an association between age groups and RTCs after adjusting for all variables, with ORs of 0.49 or less for older age groups when using age group 16-24 years as reference (p<0.001 for all age groups). Having previous speeding tickets was also significantly associated with previous RTCs after adjusting for all variables, with an OR of 1.39 (95% CI=1.08-1.80). Drug use as independent variables shows that THC was significantly associated with RTCs (adjusted OR=1.93, 95% CI=1.05-3.57).

When grouping the use of any illicit drug separately into one variable, a significant association between the use of illicit drugs and RTCs was found (OR=2.20, 95% CI=1.27-3.81), but this association was not significant after adjusting for sex, age group, speeding and the use of medicinal drugs (OR=1.68, 95% CI= 0.95-2.96). When grouping opioid analgesics, sedatives and hypnotics into one variable (medicinal drugs), a negative association with reported RTC was found (OR=0.29, 95% CI=0.11-0.78), but this was not significant after adjusting for sex and age groups (OR=0.43, 95% CI=0.16-1.19).

We did not find any significant interactions between the independent variables.

Discussion

In this study we found several factors that were associated with self-reported road traffic crash (RTC) involvement. In general, men reported more frequently to have been involved in RTCs and having received speeding tickets the previous two years compared to women, especially those in the youngest age group (16-24 years). This is in agreement with a study from the United States where men, and especially young men aged 16-25, pose the highest risk of causing fatal crashes, based on data from 2001-2003 (Eustace & Wei 2010). That study also found that speeding was the most unsafe driving action contributing to fatal crashes, and that driving errors contribute more to fatal RTCs caused by women compared to men. Also Storie et al. (1977) found that while women were involved in crashes associated with errors of perceptual nature, such as distraction, not seeing hazards and in making turning maneuvers, men were involved in drink driving and speeding-related crashes.

We also found that a larger proportion of male drivers tested positive for the use of illicit drugs or alcohol, while a larger proportion of female drivers tested positive for the use of medicinal drugs. As Buccelli et al. (2016) discusses in a review article, several studies confirm gender differences in drug use patterns, with predominantly men using illicit drugs and women using medicinal drugs, which is rooted in both sociocultural and biological differences.

The data presented in Table 2 indicated that speeding and the use of various groups of illicit and medicinal drug use were associated with self-reported RTC, and also that the use of illicit drugs was associated with self-reported speeding. From the multivariable analysis data in Table 3, we saw that after adjusting for age group and sex, the use of cannabis and previous speeding tickets was still found to be significantly associated with RTCs. While speeding itself is a risk factor for crashes (Lancaster & Ward 2002), it has also been found to be associated with other risky driving behavior, such as DUI of alcohol, stimulants and cannabis (Golias & Karlaftis 2001; Iversen 2004; Liu et al. 2016). As already mentioned, 42% of fatal RTCs were found to be related to speeding in Norway during 2005-14, while at least 21% were related to DUI of drugs or alcohol (Haldorsen 2015). When analyzing specific groups of illicit drugs and medicinal drugs, we found that only the use of cannabis had a significant association with self-reported RTC after adjusting for age group, sex and use of other substances. Previous studies have also found a significant association between the use of cannabis and fatal or injurious traffic crashes (Asbridge et al. 2012; Ramaekers et al. 2004). Blows et al. (2005) found a strong association between habitual cannabis use and previous car crash injury.

It has also been found that the combined use of cannabis and alcohol can result in synergic impairing effects (Bramness et al. 2010; Chihuri et al. 2017; Ramaekers et al. 2004). However, in our study, only one participant tested positive for both THC and alcohol.

A survey of alcohol and drug use among about 2300 persons in Norway found that 3% reported that they had been driving with BAC above the legal limit, or being passenger where the driver had BAC above the legal limit during the last year. Only 1% reported the same for drug driving (Hesjevoll & Fyhri 2017). A survey among Norwegian young adults aged 17-28 years found that 7.6% reported having driven a motor vehicle under the influence of alcohol during the previous 12 months; 11.8% of males and 4.2% among females (Moan et al. 2013). An American survey from 2014 reported higher proportions of drunk and drugged driving; 11.1% of the participants (age 16 years and older) had been DUI of alcohol the last 12 months, while 4.1% had been DUI of

illicit drugs during the same time (Lipari et al. 2016). DUI of alcohol was highest between age 21 and 24 years, where 18.9-19.4% reported DUI, and the numbers steadily declining to 4.1% of the participants 65 years and older reporting to have been DUI of alcohol. Similarly, the self-reported prevalence of DUI of illicit drugs was highest between age 20 and 22, with 12.4-12.7%, and the numbers declining to 0.2% of the participants aged 65 and older reporting to have been DUI of illicit drugs. The self-reported incidence of DUI was thus lower in Norway than in the USA.

The DRUID project, comprising roadside surveys from 13 countries in Europe from 2007 to 2009, concluded that testing positive for medicinal drugs was most prevalent in (Gjerde et al. 2013; Houwing et al. 2011). This finding may explain why those who tested positive for medicinal drugs reported less RTC involvement.

Bivariate analyses might give the impression that medicinal drugs can have a somewhat protective effect on previous RTCs, with the use of medicinal drugs conferring lower traffic crash risk, specifically the use of sedatives and hypnotics. In multivariable analysis adjusting for age group and sex, no significant association was found. Most studies involving traffic crashes and medicinal drug use have focused on benzodiazepines, indicating that benzodiazepines are associated with increased crash risk, although there seems to be a contribution from having sleep problems (Orriols et al. 2009). A Norwegian registry-based study from 2007 found that filling a prescription for z-hypnotics increased the risk of RTCs with standardized incidence ratios of 2.2-4.0 (Gustavsen et al. 2008). However, being a young and unexperienced driver seems to constitute a larger crash risk than being an elderly driver who is using benzodiazepines or similar drugs for therapeutic purposes.

The association between cannabis use and RTC involvement does not prove that cannabis use increases the risk for RTC involvement more than alcohol or other drugs. Many experimental studies have found that cannabis use affects the ability to drive safely, both driving simulator studies (Lenne et al. 2010; Papafotiou et al. 2005; Ronen et al. 2008) and on-road studies (Ramaekers et al. 2000; Robbe 1998), and epidemiological studies have also found increased crash risk associated with cannabis use (Asbridge et al. 2012; Bedard et al. 2007; Gjerde et al. 2015), although less than for alcohol impairment. Because of the increasing decriminalization and legalization of cannabis at a global level, it is likely that the incidence of driving under influence of cannabis will also increase. A road-side study from six jurisdictions in California in 2010 showed an increase in cannabis use among drivers compared to 2007 (Johnson et al. 2012). The study also found that drivers with medical cannabis permits were more likely to test positive for THC compared to non-permit users, and that drivers testing positive did not think their cannabis-use affected their driving skills. These findings might indicate that the legalization and decriminalization of cannabis has led to increased acceptance and tolerance towards use and disregard for the effects it has on driving skills.

Recreational use of cannabis is illegal in Norway, and its use is not commonly accepted in the population. It is likely that cannabis users might therefore not represent a random selection of drivers in the actual age and sex groups, but might be over-represented by individuals with risk-taking personalities or drivers with norms and attitudes that allow risk-taking behavior in road traffic. Future studies should therefore also investigate driver's attitudes towards driving after cannabis use in addition to other risk-taking behavior.

Strengths and limitations

The main strengths or this study were that information on substance use was based on analytical testing, not self-reports, and that a large number of drivers were included. The refusal rate in our study was less than 10%, which is good in this type of studies. Finally, the use of validated questionnaires and well-documented methods for analyzing oral fluid samples strengthens the findings.

The main limitation is that we have to be careful not to make strong assumptions on the association between substance use, speeding and RTC involvement because we combined drug test results from the sampling date with self-reported speeding and RTCs during the two years prior to sampling.

It is likely that some of those who declined to take part of the survey had recently been using alcohol, illicit or medicinal drugs. In addition, under-reporting of previous RTCs and speeding tickets is likely in these kinds of surveys. We have no information whether the medicinal drugs are used as prescribed or in an illegal context.

We do not know the time of drug intake or dose; it may have been taken many hours before collection of the oral fluid sample, so testing positive for a drug did not necessarily indicate driving impairment. We have no information whether the medicinal drugs that were found in the oral fluid samples had been used in accordance with prescription or for recreational use.

Due to low number of drivers testing positive for psychoactive substances, particularly for alcohol, the statistical power of this study may have been too low to identify significant associations between the use of alcohol or drugs before driving and speeding and RTC involvement.

In order to overcome some of the limitations mentioned above, a better study of the association between use of cannabis and other psychoactive substances with RTC involvement can be performed by studying drivers injured in RTCs who are treated at hospitals by analyzing alcohol and drugs in blood samples combined with questionnaires. So-called responsibility studies, a type of observational study where those responsible for the crash are compared to those not responsible (Kim & Mooney 2016), may also provide valuable data.

Conclusions

In conclusion, we found that previous speeding tickets, age and the use of cannabis were significantly associated with previous RTCs. On this background we hypothesize that more speed controls (both automatic and police-initiated random controls) may reduce speed-related RTCs. To reduce DUI-related crashes, we suggest equipping more police patrols with instruments to detect DUI of substances other than alcohol. In addition, we suggest initiation of multicomponent programs including several measures to reduce impaired driving, focusing especially on DUI of commonly used drugs such as cannabis. Such programs have been shown to be effective in reducing alcohol-related crashes (Shults et al. 2009).

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REFERENCES

Ajzen I. From Intentions to Actions: A Theory of Planned Behavior. In: Kuhl J, Beckmann J, eds. *Action Control: From Cognition to Behavior*. Berlin, Heidelberg: Springer Berlin Heidelberg; 1985:11-39.

Ajzen I. The theory of planned behavior. *Organ Behav Hum Decis Process.* 1991;50(2):179-211.

Ajzen I, Fishbein M. *Understanding attitudes and predicting social behavior.* Englewood Cliffs, NJ. Prentice-Hall; 1980.

Asbridge M, Hayden JA, Cartwright JL. Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. *BMJ.* 2012;344.

Bedard M, Dubois S, Weaver B. The impact of cannabis on driving. *Can J Public health.* 2007;98(1):6-11.

Blows S, Ivers RQ, Connor J, Ameratunga S, Woodward M, Norton R. Marijuana use and car crash injury. *Addiction.* 2005;100(5):605-611.

Bogstrand ST, Larsson M, Holtan A, Staff T, Vindenes V, Gjerde H. Associations between driving under the influence of alcohol or drugs, speeding and seatbelt use among fatally injured car drivers in Norway. *Accid Anal Prev.* 2015;78:14-19.

Bramness JG, Khiabani HZ, Morland J. Impairment due to cannabis and ethanol: clinical signs and additive effects. *Addiction.* 2010;105(6):1080-1087.

Buccelli C, Della Casa E, Paternoster M, Niola M, Pieri M. Gender differences in drug abuse in the forensic toxicological approach. *Forensic Sci Int.* 2016;265:89-95.

Chihuri S, Li G, Chen Q. Interaction of marijuana and alcohol on fatal motor vehicle crash risk: a case-control study. *Inj Epidemiol.* 2017;4(1):8.

Christophersen AS, Gjerde H. Prevalence of alcohol and drugs among car and van drivers killed in road accidents in Norway: an overview from 2001 to 2010. *Traffic Inj Prev.* 2014;15(6):523-531.

Conner M, Lawton R, Parker D, Chorlton K, Manstead ASR, Stradling S. Application of the theory of planned behaviour to the prediction of objectively assessed breaking of posted speed limits. *Br J Psychol.* 2007;98(3):429-453.

Donohew L, Clayton RR, Skinner WF, Colon S. Peer networks and sensation seeking: some implications for primary socialization theory. *Subst Use Misuse.* 1999a;34(7):1013-1023.

Donohew RL, Hoyle RH, Clayton RR, Skinner WF, Colon SE, Rice RE. Sensation seeking and drug use by adolescents and their friends: models for marijuana and alcohol. *J Stud Alcohol.* 1999b;60(5):622-631.

Earleywine M, Finn PR. Sensation seeking explains the relation between behavioral disinhibition and alcohol consumption. *Addict Behav.* 1991;16(3-4):123-128.

Earleywine M, Finn PR, Martin CS. Personality risk and alcohol consumption: a latent variable analysis. *Addict Behav.* 1990;15(2):183-187.

Elander J, West R, French D. Behavioral correlates of individual differences in road-traffic crash risk: an examination method and findings. *Psychol Bull.* 1993;113(2):279-294.

Elliott MA, Armitage CJ, Baughan CJ. Drivers' compliance with speed limits: an application of the theory of planned behavior. *J Appl Psychol.* 2003;88(5):964-972.

Elvebakk B, Steiro T. First principles, second hand: Perceptions and interpretations of vision zero in Norway. *Saf Sci.* 2009;47(7):958-966.

Eustace D, Wei H. The Role of Driver Age and Gender in Motor Vehicle Fatal Crashes. *J Transp Saf Secur.* 2010;2(1):28-44.

Fishbein M, Ajzen I. *Belief, attitude, intention, and behavior: an introduction to theory and research.* Addison-Wesley Pub. Co.; 1975.

Furuhaugen H, Jamt REG, Nilsson G, Vindenes V, Gjerde H. Roadside survey of alcohol and drug use among Norwegian drivers in 2016-17: a follow up of the 2008-9 survey. *Traffic Inj Prev.* 2018. DOI: 10.1080/15389588.2018.1478087.

Gjerde H, Christophersen AS, Normann PT, Assum T, Oiestad EL, Morland J. Norwegian roadside survey of alcohol and drug use by drivers (2008-2009). *Traffic Inj Prevention.* 2013;14(5):443-452.

Gjerde H, Strand MC, Morland J. Driving Under the Influence of Non-Alcohol Drugs--An Update Part I: Epidemiological Studies. *Forensic Sci Rev.* 2015;27(2):89-113.

Golias I, Karlaftis MG. An international comparative study of self-reported driver behavior. *Transp Res Part F Traffic Psychol Behav.* 2001;4(4):243-256.

Gustavsen I, Bramness JG, Skurtveit S, Engeland A, Neutel I, Morland J. Road traffic accident risk related to prescriptions of the hypnotics zopiclone, zolpidem, flunitrazepam and nitrazepam. *Sleep Med.* 2008;9(8):818-822.

Haldorsen I. In-Depth Analyses of Fatal Road Accidents in the year 2014. 2015. Available at: https://www.vegvesen.no/_attachment/935026/binary/1044077. Accessed August 20, 2018.

Hesjevoll I, Fyhri A. Trafikksikkerhetstilstanden 2016: Befolkningens kunnskaper, atferd og holdninger. TØI rapport 1573/2017 [Road Safety in Norway 2016- A monitor survey of knowledge, behaviour and attitudes]. 2017. Available at: https://www.toi.no/getfile.php?mmfileid=45449. Accessed August 20, 2018.

Houwing S, Hagenzieker M, Mathijssen R, et al. Prevalence of Alcohol and Other Psychoactive Substances in Drivers in General Traffic, Part I: General Results. DRUID deliverable D 2.2.3. Leidschendam, The Netherlands: SVOW Institute for Road Traffic Safety Research. 2011. Available at: https://biblio.ugent.be/publication/1988541. Accessed August 20, 2018.

Iversen H. Risk-taking attitudes and risky driving behaviour. *Transp Res Part F Traffic Psychol Behav.* 2004;7(3):135-150.

Johnson MB, Kelley-Baker T, Voas RB, Lacey JH. The prevalence of cannabis-involved driving in California. *Drug Alcohol Depend.* 2012;123(1):105-109.

Kim JH, Mooney SJ. The epidemiologic principles underlying traffic safety study designs. *Int J Epidemiol.* 2016;45(5):1668-1675.

Kristoffersen L, Smith-Kielland A. An automated alcohol dehydrogenase method for ethanol quantification in urine and whole blood. *J Anal Toxicol.* 2005;29(5):387-389.

Lancaster R, Ward R. The contribution of individual factors to driving behavior: implications for managing work related road safety. United kingdom. 2002. Available at: http://www.hse.gov.uk/research/rrpdf/rr020.pdf. Accessed August 20, 2018.

Lenne MG, Dietze PM, Triggs TJ, Walmsley S, Murphy B, Redman JR. The effects of cannabis and alcohol on simulated arterial driving: Influences of driving experience and task demand. *Accid Anal Prev.* 2010;42(3):859-866.

Letirand F, Delhomme P. Speed behaviour as a choice between observing and exceeding the speed limit. *Transp Res Part F Traffic Psychol Behav.* 2005;8(6):481-492.

Lipari RN, Hughes A, Bose J. Driving Under the Influence of Alcohol and Illicit Drugs. The CBHSQ Report. Rockville, MD, US: Substance Abuse and Mental Health Services Administration. 2016.

Liu C, Huang Y, Pressley JC. Restraint use and risky driving behaviors across drug types and drug and alcohol combinations for drivers involved in a fatal motor vehicle collision on U.S. roadways. *Inj Epidemiol.* 2016;3:9.

Lucidi F, Mallia L, Lazuras L, Violani C. Personality and attitudes as predictors of risky driving among older drivers. *Accid Anal Prev.* 2014;72:318-324.

Moan IS, Norstrom T, Storvoll EE. Alcohol use and drunk driving: the modifying effect of impulsivity. *J Stud Alcohol Drugs.* 2013;74(1):114-119.

NHTSA. Fatal Crashes Involving Young Drivers [research note]. 2009. Available at: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811218. Accessed August 2018.

Ogden EJ, Moskowitz H. Effects of alcohol and other drugs on driver performance. *Traffic Inj Prev.* 2004;5(3):185-198.

Orriols L, Salmi LR, Philip P, et al. The impact of medicinal drugs on traffic safety: a systematic review of epidemiological studies. *Pharmacoepidemiol Drug Saf.* 2009;18(8):647-658.

Papafotiou K, Carter JD, Stough C. The relationship between performance on the standardised field sobriety tests, driving performance and the level of Delta9-tetrahydrocannabinol (THC) in blood. *Forensic Sci Int.* 2005;155(2-3):172-178.

Penning R, Veldstra JL, Daamen AP, Olivier B, Verster JC. Drugs of abuse, driving and traffic safety. *Curr Drug Abuse Rev.* 2010;3(1):23-32.

Phillips DP, Brewer KM. The relationship between serious injury and blood alcohol concentration (BAC) in fatal motor vehicle accidents: BAC = 0.01% is associated with significantly more dangerous accidents than BAC = 0.00%. *Addiction.* 2011;106(9):1614-1622.

Ramaekers JG, Berghaus G, van Laar M, Drummer OH. Dose related risk of motor vehicle crashes after cannabis use. *Drug Alcohol Depend.* 2004;73(2):109-119.

Ramaekers JG, Robbe HW, O'Hanlon JF. Marijuana, alcohol and actual driving performance. *Hum Psychopharmacol.* 2000;15(7):551-558.

Robbe H. Marijuana's impairing effects on driving are moderate when taken alone but severe when combined with alcohol. *Hum Psychopharmacol.* 1998;13(S2):S70-S78.

Ronen A, Gershon P, Drobiner H, et al. Effects of THC on driving performance, physiological state and subjective feelings relative to alcohol. *Accid Anal Prev.* 2008;40(3):926-934.

Shapiro CE, Kim F. Differential Determinants of Young Adult Substance Use and High-Risk Sexual Behavior1. *J Appl Soc Psychol.* 2002;32(6):1124-1150.

Shults RA, Elder RW, Nichols JL, Sleet DA, Compton R, Chattopadhyay SK. Effectiveness of multicomponent programs with community mobilization for reducing alcohol-impaired driving. *Am J Prev Med.* 2009;37(4):360-371.

Skjønborg Ø, Bjelkemyr-Østvang K, Pasnin L, Klemmetsen J, Bonde C. Analyse av dødsulykker og straffesaksbehandlingen i trafikksaker. Publikasjon nr. 2/2015. Oslo: Riksadvokaten; 2015. Available at: https://www.riksadvokaten.no/wp-content/uploads/2017/10/Analyse-av-dødsulykker-og-staffesaksbehandlingen-i-trafikksaker.pdf. Accessed August 21, 2018.

Statistics Norway. *Road traffic accidents involving personal injury [Statistics]*. 2018. Available at: https://www.ssb.no/en/transport-og-reiseliv/statistikker/vtu/aar. Accessed August 20, 2018.

Storie VJ. *Male and female car drivers: Differences observed in accidents.* Crowthorne, Berkshire: Accident Investigation Division, Safety Department, Transport and Road Research Laboratory; 1977.

Stubig T, Petri M, Zeckey C, et al. Alcohol intoxication in road traffic accidents leads to higher impact speed difference, higher ISS and MAIS, and higher preclinical mortality. *Alcohol.* 2012;46(7):681-686.

Vindenes V, Jordbru D, Knapskog AB, et al. Impairment based legislative limits for driving under the influence of non-alcohol drugs in Norway. *Forensic Sci Int.* 2012;219(1-3):1-11.

Vindenes V, Aamo T, Innerdal C, et al. Revidering av "forskrift om faste grenser for påvirkning av andre berusende eller bedøvende middel enn alkohol m.m." -- Vurdering av eksisterende fastegrenser og forslag til faste grenser for flere stoffer [Revision of "regulations on fixed limits for impairment by other intoxicating or anaesthetic/sedative substances than alcohol etc." --Assessment of existing fixed limits and proposed fixed limits for more substances]. Oslo, Norway: Ministry of Transport and Communications. 2015. Available at: https://www.regjeringen.no/contentassets/21dac5b787734d7b80f45d30c88e8632/hbrev2304rapport.pdf. Accessed August 20, 2018.

World Health Organization. Road Traffic Deaths 2013. 2017. Available at: http://apps.who.int/gho/data/node.main.A997. Accessed August 21, 2018.

Yang J, Du F, Qu W, Gong Z, Sun X. Effects of personality on risky driving behavior and accident involvement for Chinese drivers. *Traffic Inj Prev.* 2013;14(6):565-571.

Zuckerman M, Neeb M. Demographic influences in sensation seeking and expressions of sensation seeking in religion, smoking and driving habits. *Pers Individ Dif.* 1980;1(3):197-206.

Table 1: Characteristics of study participants.

	Total	Male	Female	*p*
Participants (%)	5031	3380 (67.2%)	1651 (32.8%)	
Age (mean)	45.4	45.9	44.1	
Speeding (%)	715 (14.2%)	544 (76.1%)	171 (23.9%)	<0.001
Road traffic crash (%)	442 (8.8%)	311 (70.4%)	131 (29.6%)	0.136
Illicit drugs				
THC	72 (1.4%)	61 (84.7%)	11 (15.3%)	0.001
Stimulants[a)]	26 (0.5%)	25 (96.2%)	1 (3.8%)	0.002
New psychoactive substances[b)]	1 (0.0%)	1 (100.0%)	0 (0.0%)	0.485
Medicinal drugs				
Opioid analgesics[c)]	54 (1.1%)	33 (61.1%)	21 (38.9%)	0.339
Sedatives and hypnotics[d)]	105 (2.1%)	45 (42.9%)	60 (57.1%)	<0.001
Alcohol	15 (0.3%)	14 (93.3%)	1 (6.7%)	0.031

[a)] **Stimulants:** amphetamine, methamphetamine, MDMA (ecstasy), cocaine and benzoylecgonine. [b)] **New psychoactive substances:** 5F-APINACA. [c)] **Opioid analgesics:** buprenorphine, codeine, methadone, morphine and tramadol. [d)] **Sedatives and hypnotics:** 7-aminoclonazepam, diazepam, nordiazepam, clonazepam, phenazepam, meprobamate, nitrazepam, oxazepam, phenobarbital, zolpidem and zopiclone.

Table 2: Bivariate associations between the use of alcohol, illicit and medicinal drugs and speeding ticket and road traffic crash involvement.

Factor	Speeding ticket			Road traffic crash involvement		
	No N (%)	Yes N (%)	*p*	No N (%)	Yes N (%)	*p*
Speeding ticket (No)				3959 (97.7)	357 (8.3)	0.002
Speeding ticket (Yes)				630 (88.1)	85 (11.9)	
Illicit drugs (No)	4245 (86.0)	693 (14.0)	0.008	4512 (91.4)	426 (8.6)	0.004
Illicit drugs (Yes)	71 (76.3)	22 (23.7)		77 (82.8)	16 (17.2)	
THC (No)	4259 (85.9)	700 (14.1)	0.105	4532 (91.4)	427 (8.6)	0.000
THC (Yes)	57 (79.2)	15 (20.8)		57 (79.2)	15 (20.8)	
Stimulants (No)	4297 (85.9)	708 (14.1)	0.063	4567 (91.2)	438 (8.8)	0.233
Stimulants (Yes)	19 (73.1)	7 (26.9)		22 (84.6)	4 (15.4)	
Medicinal drugs (No)	4188 (85.7)	698 (14.3)	0.384	4448 (91.0)	438 (9.0)	0.009
Medicinal drugs (Yes)	128 (88.3)	17 (11.7)		141 (97.2)	4 (2.8)	
Sedatives and hypnotics (No)	4223 (85.7)	703 (14.3)	0.409	4486 (91.1)	440 (8.9)	0.012
Sedatives and hypnotics (Yes)	93 (88.6)	12 (11.4)		103 (98.1)	2 (1.9)	
Opioid analgesics (No)	4269 (85.8)	708 (14.2)	0.792	4537 (91.2)	440 (8.8)	0.185
Opioid analgesics (Yes)	47 (87.0)	7 (13.0)		52 (96.3)	2 (3.7)	
Alcohol (No)	4302 (85.8)	714 (14.2)	0.402	4575 (91.2)	441 (8.8)	0.772
Alcohol (Yes)	14 (93.3)	1 (6.7)		14 (93.3)	1 (6.7)	

Table 3: Adjusted odds ratios for the association between RTCs and sex, age group, speeding tickets and the use of various groups of illicit and medicinal drugs and alcohol.

Independent variables	Road traffic crash	
	OR (95% CI)	
	Crude	Adjusted
Sex (Male)	1.18 (0.95-1.46)	1.17 (0.94-1.46)
Age group 16-24 (Reference)		
Age group 25-34	0.50 (0.37-0.66)***	0.49 (0.36-0.65)***
Age group 35-44	0.24 (0.17-0.33)***	0.24 (0.17-0.34)***
Age group 45-54	0.29 (0.21-0.39)***	0.30 (0.22-0.40)***
Age group 55-64	0.23 (0.16-0.32)***	0.24 (0.17-0.34)***
Age group 65+	0.16 (0.10-0.25)***	0.17 (0.11-0.27)***
Speeding (Yes)	1.50 (1.16-1.92)**	1.39 (1.08-1.80)*
THC (Yes)	2.79 (1.57-4.98)***	1.93 (1.05-3.57)*
Alcohol (Yes)	0.74 (0.10-5.65)	0.54 (0.07-4.30)
Stimulants (Yes)	1.90 (0.65-5.53)	1.34 (0.43-4.19)
Opioid analgesics (Yes)	0.40 (0.10-1.63)	0.67 (0.16-2.80)
Sedatives and hypnotics	0.20 (0.05-0.81)*	0.33 (0.08-1.35)

*p<0.05, **p<0.01, ***p<0.001. The model was adjusted for sex, age group, speeding, use of THC, alcohol, stimulants, opioid analgesics and sedatives and hypnotics.